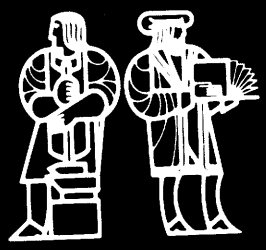
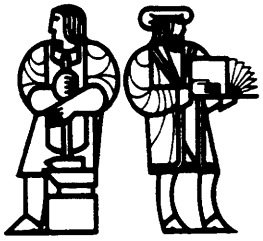
Massachusetts Institute of Technology



Reports to the President

For the Year Ended
June 30, 1992

Massachusetts Institute of Technology



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For the Year Ended
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1991–92

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"A slow sort of country!" said the Queen. "Now here, you see, it takes all the running you can do, to keep in the same place. If you want to get somewhere else, you must run at least twice as fast as that!"

Lewis Carroll, *Through the Looking Glass*

EXCELLENCE IN AN ERA OF CHANGE AND CONSTRAINT

America's research universities are faced with a central challenge – to retain and enhance excellence in a time of fiscal constraint and societal uncertainty. We are experiencing a deep sense of frustration because never in our history has the field of intellectual challenge and opportunity or the need for our services to the nation and the world been so great; yet never in recent decades have we experienced such fiscal constraint or sensed such a fall from grace with the public and the government. We are not in crisis, but we are in a precarious state, one that may be more difficult to grasp and respond to than crisis.

But respond we must, because this is a time in which we at MIT and our colleagues around the country should solidify and expand our roles as leaders in this increasingly complex world. We must define new disciplinary futures and invent new intellectual pathways to understanding the physical, biological, economic, and artistic universes. It is a time in which we must do our part in shaping the future.

The challenges before us are great. We must:

- continue to lead the revolution in molecular biology and advance the promise of biotechnology;
- come to understand the workings of the human brain and the nature of intelligence;
- bring the highest quality of mind to assessing and ameliorating humankind's effects on the earth's environment;
- secure the advances of computers, communications technology, and the information marketplace for the social good;
- better understand organizations and businesses and how to make them more effective in building vital and sustainable economies;
- combine the aesthetic and the technical in the design of the physical environment and in the creation of more livable cities;
- renew – through our unique intellectual and creative environment – the liberal, visual, and performing arts that in such large measure define what it is to be human.

LEADERSHIP AND MANAGEMENT

University presidents, provosts, deans, department heads, laboratory directors, and other academic administrators rightfully understand their tasks to be to lead and serve, rather than to manage in a narrow sense. Universities are not, and must never become, simply businesses. Our essence and our human purpose run far deeper than that. Nonetheless, leadership for the 1990s requires an understanding of rapidly shifting conditions, opportunities, and resources. The human resources of America's research universities are truly extraordinary, but our fiscal resources are dwindling in real value. I believe that the times require of us uncommon attention to financial and organizational planning and, indeed, management. This attention must come not only from administrators, but also from faculty and staff throughout the academic community. We must all act concertedly, and with wisdom and dispatch, if we are to serve our societal purposes.

FORCES

The budgets of American universities have been affected for the last several years by opposing forces. On one side we are faced with declining rates of revenue increases and a general decline in the climate for support of higher education. Dominant factors include the concern of students and their families about college costs, a leveling trend in federal resources for education and university research, and a loss of national will to address the broad spectrum of the country's educational needs.

On the other hand, we are faced with increasing costs, expectations, and obligations. The cost of what we already do is rising, and there is an escalation in what we expect of ourselves and what society expects of us.

One of the fastest growing components of most campus operating budgets has been student financial aid. The combination of rising tuition, rapidly declining federal scholarships and grants, and more recently, the effects of the national recession on family incomes has rapidly accelerated the need for financial aid. Federal grants to students have declined in real value by a factor of two since 1980. As recently as 1975, 70 percent of federal student aid was in the form of scholarships and 25 percent was in the form of loans. Following the trend of so many other things in our society, by 1991, only 31 percent of federal student aid was in the form of grants, while 66 percent was in the form of loans.

At MIT, 45 percent of MIT's student aid came from the federal government in 1975, compared with 31 percent in 1991. In 1975, the federal government provided 19 percent of scholarship grants at MIT, while the Institute provided 67 percent. By 1991, the federal portion had dropped to 11 percent, while MIT provided 81 percent. The reduction in the level of federal support, and the shift from grants to loans, have significant financial consequences that have been borne by the Institute.

Research universities are subjected to strong market forces associated with hiring new faculty members of the highest quality. Salary competition is pervasive, and the costs that universities are expected to bear in order to start the research career of a new faculty member in many branches of science and engineering are measured in hundreds of thousands of dollars. In many fields, the bidding for faculty members

has included the promise of greatly reduced teaching loads – a trend that we must resist.

Establishment of a healthy and vigorous research environment is often very expensive. Major costs include modern equipment and instrumentation and the associated technical support staff.

During the past decade, the revolution in information technology has brought with it an indispensable but very costly budget line that hardly existed theretofore. Microcomputers and workstations, campus network infrastructures, and the corresponding staff to manage and maintain information systems have become pervasive and essential features of university campuses. The demand for increasing capacity, speed, and sophistication has accelerated rapidly. This revolution has expanded greatly the breadth and complexity of educational and research topics with which we can deal. Yet these advances are costly. It is already common for 2 or 3 percent of a campus operating budget to be associated with information technology.

Libraries, even in their most traditional form, have been sources of particular cost escalation. The cost of acquisition, storage, and preservation of scholarly books and journals has grown rapidly during the last decade or two, and most libraries have also had to carry the capital investment in automation of many of their records and functions. As we have moved into new optical and electronic forms of information storage, libraries have tended to add to, rather than replace, traditional printed materials. Every campus library has been engaged in cutting back on the numbers of its journal subscriptions and book acquisitions. Yet during the last two decades journal subscription rates have often risen by many tens of percents in a year.

Not surprisingly, there is a rather large litany of regulatory and legal matters, as well as social mandates, that have caused costs to grow very rapidly on campuses. Issues of campus safety, access for the disabled, substance abuse monitoring, financial aid eligibility of students, conflict of interest matters, investigations of research misconduct, environmental regulation, the compliance reporting associated with affirmative action, matters of sexual harassment, and a variety of personnel issues in an increasingly litigious society are but a few of the many and substantial costs that are of relatively recent origin.

New intellectual trends, especially the growing importance of organizing to conduct highly interdisciplinary research and education, tend to bring new organizational overhead with them. The formation of new laboratories, centers, and institutes is sometimes encouraged by research sponsors, and is often believed to be necessary, in order to conduct many interdisciplinary activities. These new organizations often require new space, as well as additional staff and services.

The past two decades have brought an expanded societal role for many of our colleges and universities. We all share a responsibility to be more reflective of the rapidly changing racial and ethnic makeup of our nation, and a need to make all career paths fully accessible to minorities and women. In addition, institutions have increasingly assumed, or had thrust upon them, various roles in the economic development of their states or regions. The daunting problems facing primary and secondary education have led many universities to undertake a variety of active roles in the improvement of K-12 systems and curricula.

Finally, there are many new services that we have either taken on, or very much wish we could better assist with, as socially responsible employers. These services reflect the changing nature and economic characteristics of the families and careers of our faculty and staff. Matters such as health care, child bearing, child care, housing and retirement, not to mention care of the elderly, all impose new or rapidly growing costs or potential costs upon our institutions.

New tasks, new roles, and new responsibilities – but no corresponding new revenues – have become a familiar situation in academe.

A NATIONAL PERSPECTIVE

Academia today exemplifies the adage that misery loves company. Last year, nearly 85 percent of the nation's colleges and universities reported that securing adequate financial support was one of their three most serious challenges. During 1990-91, 45 percent of our colleges and universities announced mid-year budget cuts. This was not a one-time anomaly; 57 percent implemented mid-year cuts during 1991-92. The budgets of public universities, because they are subject to the variations and changing priorities of state legislatures and administrations, tend to fluctuate more rapidly and over a wider range than those of private institutions. But the basic financial trends of both types of institutions are depressingly similar, and the private institutions have fewer options available to them for the long range amelioration of their financial problems.

To put higher education's revenues into some historical perspective, we must examine both how the levels and sources of revenue have changed and also how the use of those revenues has varied. The total operating budgets of all public and private doctoral-granting universities grew in constant dollars by 109 percent, from $31 billion to $65 billion during the last 20 years. More than doubling operating budgets in 15 years hardly seems like austerity, so why are we sensing such constraint? The answer seems to be twofold: we are taking on more tasks and we are teaching more students. Enrollments have grown (99 percent in public institutions and 50 percent in private institutions) during the last twenty years, continuing to grow monotonically even during the years in which the number of 18-24 year olds in the US declined by more than 20 percent.

The operating revenue of private, doctoral-granting institutions has grown from roughly $12 billion to around $23 billion in constant dollars during the last twenty years. The most dramatic change in the source of these funds is that the federal government supplied nearly 30 percent twenty years ago, but only about 18 percent today. The fraction of operating revenue (26 percent) derived from tuition and fees has increased slightly during this period, while that arising from endowment has remained constant at about 9 percent. During this period, the fraction of operating revenues derived from auxiliary activities, including hospitals and federally funded research and development centers, has increased substantially, from 29 percent to 40 percent. The trends for public universities are similar, but, of course, they have a high dependence on state support (approximately 40 percent across all such schools, but with wide variations among them).

Tuition across the country, especially that of private universities, has rather consistently followed the ups and downs of variations in the consumer price index (CPI), but for fifteen years the annual increases have been greater than the CPI. This is because the cost of the majority of goods and services needed by universities – such as scholarships and fellowships, books and journals, faculty and staff salaries – tends to rise more quickly than the CPI. Hence, while general inflation has been a primary driver of tuition, the specific costs borne by tuition have grown even more rapidly. It should be noted that while the tuition of the major private universities grew by nearly 300 percent from 1976 to 1991, its real growth, i.e., growth adjusted for inflation, was 55 percent. Interestingly, the contribution of tuition to the operating budgets of these universities grew by only about 3 percent during the past fifteen years.

MIT'S BUDGET

How is MIT's budget faring in the current climate? The simple answer is that we are in a stronger position than many of our sister institutions, but that the forces on our budget have reached a critical point, one that requires concerted, Institute-wide action if we are to remain excellent and rebuild some flexibility to do the things that we believe to be important.

Our situation differs somewhat from that of most research universities. Because of our focus on science and engineering, and the consequent dependence on federal funding, we are particularly sensitive to government policy and budgetary changes. On the positive side, our historically strong relations with the private sector are important and growing assets.

To examine our current situation, note that we have only three primary sources of revenue – tuition, federal and industrial research funds, and private support, including gifts and investment income.

Tuition rates are set annually at the Institute's discretion, but obviously must reflect the realities of the nation's economy, the corresponding need to supply financial aid, and our desire to remain accessible to bright students regardless of their family's financial situation. While tuition will continue to grow somewhat, MIT has begun to slow its rate of growth; this year's increase was 6.5 percent, the second lowest increase in 20 years.

Federal research support is earned by the efforts, innovation, and high intellectual quality of MIT's faculty, but it also depends on the congruence of our goals with those of the federal government and is subject to the shifting nature of the federal/ university partnership. Research support at MIT has nearly leveled out during the last two years.

Private support is received in the form of gifts, grants, and bequests from alumni, alumnae, and friends of the Institute and from foundations and corporations. The development of private support requires considerable concerted effort and stewardship, and ultimately is a function of our institutional quality. Donations to MIT have increased very substantially during the five years of the *Campaign for the future,* and our endowment has grown from $1.2 billion to $1.6 billion in market value over

that period, while total invested funds have increased in market value from $1.4 billion to $1.95 billion.

The state of the budget is crystallized when we set tuition levels and, of course, when we balance costs and revenues. Flattening research income, despite the increase in private support, has left us in a position in which there is nearly a direct relationship between annual tuition increases and the magnitude of faculty and staff salary increases. This is not a healthy circumstance. I believe that we must constrain the rate at which tuition grows, but also that we must retain our ability to pay the salaries and wages required to retain and appropriately reward faculty and staff of the highest quality. This dilemma must be resolved.

MIT's endowment grows through the receipt of gifts and the investment of its funds. During the period of the *Campaign for the future,* we have done well by both measures. For example, we have been able to create 58 new full professorial chairs and 33 career development professorships. Each year we spend a portion of the interest earned by the endowment equaling between 4.5 and 5.0 percent of its principal. Of course, on the average, the endowment earns more than this, but by policy we plow the difference back into the principal of the endowment so that it will grow at least at the rate of inflation. In this way, we maintain the purchasing power of the endowment over time so that, for example, professorial chairs and student fellowships retain their value in perpetuity.

There are two key measures to consider when we attempt to balance our operating budget – the deficit and the operating gap. The operating gap is the difference between our expenditures and directed revenues such as tuition, research funds, fees for service and most endowment income. This gap must be filled by discretionary resources in the form of annual unrestricted gifts, grants, and bequests. If the addition of these discretionary resources still does not bring our available resources to the level of our expenditures, we are left with a deficit. For the past 15 years, the operating gap has averaged around $5.7 million, but for the last three years this gap has ranged between $9 million and $13 million. The deficits between 1976 and 1988 were very modest, averaging nearly zero, with small surpluses in a few years. In 1989 and 1990, deficits grew to around $4.5 million. In 1991 we were able to bring it down to $300,000, but only because there was an unexpectedly large amount of unrestricted gifts and bequests received that year to fill the operating gap. In 1992 our deficit grew to $6.3 million.

The result of recent budgetary pressures, therefore, has been that our annual deficit has been running at about $5 million and is projected to increase further. This is troubling. Despite the fact that this is less than one percent of the campus operating budget, it is clear to all who have observed the federal deficit that, if unchecked, its effect will grow over time and leave an unfair penalty for the Institute in the downstream years. In my view, however, it is the development of a decidedly substantial, structural operating gap of at least $10 million that is of the most serious concern. The use of much of our annual, unrestricted gift income to fill the operating gap represents a loss of flexibility to fund new initiatives, to seed innovative educational and research projects, and to ameliorate our growing financial aid burdens. It also does not bode well for the appropriate compensation of faculty and staff if this situation is left unchecked.

GROWTH

A recent examination of the growth of faculty, students, and staff at MIT over the last 15 years indicated that in many ways our trends are similar to those of other major research universities around the country, although in one important measure, faculty size, we are somewhat distinct. We have maintained an essentially constant faculty headcount during this period while many other institutions expanded. Currently, we have 966 assistant, associate, and full professors, 73 percent of whom are tenured. The discipline of maintaining this constant faculty size, I believe, has lessened the depth of financial pressures at MIT relative to that at some universities, but it has not eliminated them.

MIT's undergraduate enrollment has stayed essentially stable at 4,300, while our graduate enrollment has grown by almost 1,000 – to 5,200 – during this period.

As at virtually every other research institution, there has been an increase in staff during this fifteen year period, especially during the first few years. Administrative, support, and service staff have increased roughly 7 percent, from 3,699 in 1976 to 3,976 in 1991. Why? This growth was the result of such factors as an increase in services required by faculty for their research and educational activities, a 70 percent growth in the headcount of other academic staff,* the increasing bureaucratic overhead required to conduct sponsored research programs and to comply with the upward spiral of federal regulation, the establishment of a pervasive computing environment, the establishment of a major organization for fund raising, and the development of a comprehensive medical department. Simply put, we have grown in complexity in response to enhanced internal needs and expectations and to externally imposed requirements. Unfortunately, many of these new tasks have not brought with them new revenues.

It is fair to say that by far the bulk of growth of administrative, support, and service staff has been driven by academic needs. Indeed, the size of the staff on the administrative side of the house (i.e., those reporting to the vice presidents) is at virtually the same level (2,200) as in 1976, having grown slightly and then been reduced in the early 1980s. The administrative, support, and service staff in the academic sectors (schools, departments, and laboratories), however, has grown by 16 percent – from 1,481 to 1,721 – during this period, reflecting the increasing need and demand for academic support services. Similarly, research staff increased in headcount by 47 percent – from 650 to 953. Each of these additions has been a conscious, local decision, ultimately agreed to through the deans or directors and the provost.

REVENUE ENHANCEMENT

There are only two ways to bring a budget into balance – increase revenues or cut costs. In my view, both are called for at the present time. In examining both options we must always remember the obvious – our mission is not a financial one; it is one of teaching, research, and service. Our revenues are only the means to an end, and

* Other academic staff includes instructors, technical instructors, lecturers and senior lecturers, adjunct faculty, visiting faculty, postdoctoral fellows and associates, senior research scientists, visiting scientists, coaches, and medical staff.

the structure of our budget should be a direct reflection of our substantive goals and aspirations.

I am confident that the excellence of our faculty and students and the quality and innovative nature of faculty activities will assure that our federal research support will remain strong. But there are two caveats. First, by small step upon small step, federal agencies are backing away from paying the full costs of the programs that they sponsor, including research and fellowships. Second, the directions of federal research policy are in flux as a natural consequence of the end of the Cold War era and because of the advent of new concerns associated with issues such as the environment, health care, and industrial competitiveness. America's research universities must respond to these changing conditions, but more importantly, have a responsibility to help shape policies and programs in the national interest.

There are many object lessons and reasons for optimism in recent MIT initiatives. Let me cite two – the Leaders for Manufacturing Program and the MIT Japan Program. Leaders for Manufacturing is an innovative master's level program designed and implemented in close working partnership with several US manufacturing firms to educate a new breed of managers and engineers equipped with a broad, integrated understanding of manufacturing and management science, technology, and organization in a contemporary, international context. The MIT Japan Program provides a number of MIT undergraduates with in-depth Japanese language training, combined with education in Japanese culture, history, and business practice, and places them, upon graduation, as interns in Japanese industrial and research organizations. These students then return to the US with a detailed working knowledge and understanding of Japanese practices and techniques, as well as with the general benefits of international acquaintances and cultural experiences. Both of these programs respond to a clear national need; both are conducted in a world-class manner; and both have created very substantial new revenue streams for operations and student support, because the importance and effectiveness of the investment have been made clear to corporations and to the government. It also should be noted that both are primarily educational activities.

We should move forward with confidence that programs conceived with excellence, educational innovation, and long-term economic and social relevance will still find appropriate partners and sponsors. These partners and sponsors should come increasingly from the private sector, but it would be unrealistic to imagine that this will to a major extent replace federal funding. It remains a necessary function of the federal government to support the advanced education and research on which the future so directly depends.

We and our colleagues must continue to press for federal support of the full costs of programs, and to press for merit as the prime determinant of grants, contracts, and facility funding. Academic earmarking has reached the extraordinary level of nearly a billion dollars in the new federal budget – more than was contained in the total of budgets during the previous decade. Although we must recognize legitimate concerns such as geographic distribution, it is not in the interest of the country to cut off the tops of its mountains in order to fill in the valleys. Surely the wisest policy for the country cannot be random selection for awards, based on the location of schools in particular congressional districts, and funded with monies removed from the already stressed resources of programs and agencies. The great public and private

institutions must be maintained. They are magnets for the best thinkers and researchers, and their facilities and graduate schools are the peaks of excellence to which students from schools and colleges all over the country aspire and matriculate. The set of these institutions is dynamic, with new universities moving into its ranks the old fashioned way – by hard work and good ideas.

Having said this, the clear prognosis remains that the rate of growth of federal funds is being attenuated and the number of universities capable of productively conducting high-quality research and education is expanding. Substantial growth in overall research funding is therefore unlikely in the near term.

The outlook for private support is something of a mixed message. Through the very successful *Campaign for the future,* we have significantly increased MIT's level of private support. Our alumni, alumnae, as well as our staff and faculty, have worked very hard and effectively to make this happen. We must meet the challenge of continuing the momentum generated by the campaign. Resource development will need to become more deeply ingrained in the MIT culture. Continuing to increase the level of private support will be a strong challenge, but one that I have confidence we can meet.

The other side of private support, of course, is that the real value of our endowment depends on the performance of the market and the quality of our investment strategies. Our track record is good, but it also appears to most observers that returns will not be as great in the coming years as those that were possible during the last decade. Thus, major expansion of private support is somewhat problematic.

LEARNING INSTITUTIONS

We cannot assume that the resources of universities in general, and of MIT in particular, will grow significantly in the years immediately ahead. Thus, the only way to assure that we maintain excellence and have the flexibility to strike out in exciting new intellectual directions, to be a high quality employer of faculty and staff, and, above all to meet our responsibilities to our students and the nation, is to do less, do different things, or gain efficiency. In my opinion, we must do all three. Indeed, there is no choice. We must be as open to new ways of thinking about how we operate and how we teach as we are to new lines of research and scholarly inquiry.

Universities must thoughtfully and continuously review and prune their programs and organizations in addition to creating new ones as times and intellectual frontiers change. Similarly, we must continuously review and renew the services that we provide to our faculty and students. Only in this way can we assure the excellence of what we are and what we do.

I am fond of quoting Frederick Terman, an MIT alumnus who became engineering dean and provost at Stanford. When once asked whether he wanted his university to be a teaching institution or a research institution, he replied that it should be a learning institution. Today, universities must also be learning organizations in the sense developed by Peter Senge of the Sloan School of Management: organizations that come to understand and react wisely to the opportunities and constraints they face. We must study the work of our own management scholars and we must learn

from the substantial transformations of industries and other organizations around the world during the last decade or two.

The MIT Ad Hoc Faculty-Administration Committee on Indirect Costs and Graduate Student Tuition, for example, has proposed an MIT Quality Initiative to adopt the principles and lessons of Total Quality Management (TQM) within the Institute. I would use the term 'adapt' rather than 'adopt,' because we are a university, not a manufacturing or commercial service organization. However, the results of quality initiatives in a variety of settings have been so substantial that we cannot afford not to commit ourselves to serious exploration, experimentation, and implementation of these concepts and techniques.

In fact, there are three major areas in which such activities are already underway. First, the entire Information Systems group has for several months been studying and planning full-scale implementation of a TQM program to improve their service to the Institute community and to gain efficiencies in their operations. Second, campus departments that provide human services, ranging from Admissions to the MIT Press, and from Personnel and Public Relations to the Medical Department, have been meeting and working with external and internal experts to develop an approach to quality management that is appropriate for the MIT culture and that merges with their Building on Differences program – a program designed to enhance productivity and the quality of professional life in an organization of highly diverse individuals. Third, a faculty initiative resulted in a major grant from the IBM Corporation that made possible a week-long seminar in their facilities that was attended by 50 faculty members and 25 staff and administrators from MIT in early September. The opportunity for this cross section of the Institute community to study and plan together how to enhance the excellence of all that we do as an institution was extraordinary. We shall build upon the momentum developed by this group.

It is my belief that we must increasingly consider and operate MIT as an integrated organization. Our faculty, students, and staff must act more as a seamless community. Despite the fact that we must always be an environment in which individual achievement and disciplinary excellence are fostered, we must pay increasing attention to integrated activity and teamwork. In research and education, new approaches to teamwork and interdisciplinary problem solving are flowing naturally from the complexity of many of the most interesting areas of modern research and scholarship. Similarly, institutional complexity and constraint require that we approach our administrative support activities with greater communality of purpose and explicit cross linkage.

We must in these and many other ways seek to improve the quality and efficiency of our support services. But these efforts must also touch the heart of what we do – teaching and research. Are we teaching the right courses in the right way? Do we maintain archaic approaches to classrooms and laboratories? Are we making the appropriate use of the very information technologies that we develop here? Is the information flow among faculty, students, and administrators designed to enlighten or to generate entropy? Can we gain greater efficiency in the more mundane of our duties in order to free time and resources for the really important aspects of academia? Do we have too many committees? Do we have the proper balance of formal and informal contact with our students? Are research proposals prepared in such a way that faculty can concentrate on their essence and quality rather than the

bureaucratic details? Do we communicate effectively with the public, the government, the business world, and our alumni and alumnae? Are there redundancies in our operations? Do we consciously determine where we should cut back in order to make new programs possible? Do we maintain the proper balance of teamwork and individual activity? Do we allow responsibility to be exercised and decisions made at the levels where knowledge and understanding are greatest? Do we strike the congruence between the goals and needs of the Institute as a whole with those of individuals within it? Do we plan for, and invest our intellectual and financial resources in the future, or squander them on issues of the moment? Do we learn and improve as an organization as well as individually?

ENSURING THE FUTURE

Our times are times of change and uncertainty...and promise. In four decades, we have moved from an era in which the United States produced over half of the world's gross product to one in which we produce just over 20 percent. It is a world in which challenges of energy, environment, and human survivability are becoming paramount. It is a world in which idealism and concern for our fellow men and women have become rare commodities.

And yet, it is a world in which our understanding of the basic nature of life and of the physical universe is expanding exponentially. It is a world in which the integration of knowledge across seemingly disparate disciplines is producing startling new insights and intellectual directions. It is a world in which the range of temporal and physical scales with which engineers and scientists can operate has become vast beyond belief. It is a world in which the blending and cross-currents of among men and women of different races and cultures can give rise to new synergies for the advancement of civilization.

It is a world in which we at MIT can and must dream of new futures. And as we do, we must cherish those values that have made us great. We must demand excellence. We must celebrate both the solitary, iconoclastic scholar and the multidisciplinary group. We must value both abstract thought and practical application. We must treasure both the diversity of our community and the communality of our deeply rooted values. We must, in sum, hold to a vision of MIT that draws on the best we have and the best we are, and that gives to the world the full measure of our talent and imagination.

These are the things that are at stake as the economic and societal under-pinnings of the American research university, and of MIT in particular, shift and change. These changes must be met with a clear-headed view of financial realities. We must be both prudent and farsighted, and we must act carefully but decisively to shape our finances, our activities, and our organization in order to retain and enhance the excellence that is so critical to a vibrant future for ourselves and for our fellow men and women.

Charles M. Vest
October 1992

In Special Recognition

This eventful year saw a number of changes within the faculty and staff of MIT, including the appointment in June of a new Dean of the School of Architecture and Planning.

He is Professor William J. Mitchell, who came to MIT from his post as Director of the Master in Design Studies Program at Harvard University Graduate School of Design. Prior to his association with Harvard in 1986, he was on the faculty at the University of California at Los Angeles, where he was Head of the Architecture/Urban Design Program from 1980 to 1986. A native of Australia, he was educated at the University of Melbourne, Yale University, and the University of Cambridge. His scholarly interests include computer-aided design and urban planning, and he has been active in professional activities related to these interests.

Professor John de Monchaux concluded his term as Dean of the School of Architecture and Planning after almost 11 years in that role. Professor de Monchaux remains at MIT as a professor in the Departments of Architecture and Urban Studies and Planning. During his tenure as dean, Professor de Monchaux contributed to the leadership of the Institute in a wide range of matters, with a particular interest in the physical appearance of the campus. In his School, he has provided exemplary leadership in effectively addressing the urgent problems of financial aid, academic computing, affirmative action, and space.

This past year, the Provost announced a major reorganization in the administration of undergraduate education and academic support under which those activities, as well as graduate education, now report directly to the provost.

Professor Sheila E. Widnall was named Associate Provost with responsibilities in several areas, including federal relations, international education, academic integrity, and faculty retirement, promotion and tenure policies. Dr. Widnall, Abby Rockefeller Mauze Professor in the Department of Aeronautics and Astronautics, has spent considerable time in Washington as a member of the National Academy of Sciences' Panel on Scientific Responsibility and the Conduct of Research and as past president of the American Association for the Advancement of Science.

Professor Arthur C. Smith, who had been Dean for Student Affairs or acting dean since July 1990, was appointed Dean for Undergraduate Education and Student Affairs. His expanded responsibilities include curriculum support, ROTC, UROP, and the writing requirement. Dr. Smith, professor of electrical engineering, former graduate officer in the Department of Electrical Engineering and Computer Science, and former chairman of the faculty, has long been an effective advocate for the Institute's students.

Professor S. Jay Keyser, who has been Associate Provost for Educational Programs and Policy since 1985, was given the new title of Associate Provost for Institute Life, with a broad charter to build collegiality at MIT. He is focusing on the quality of life at the Institute, addressing, among other issues, the policy aspects and educational programs on how to deal with harassment. Dr. Keyser is the Peter de Florez Professor of Linguistics in the Department of Linguistics and Philosophy.

Professor J. David Litster, who had served as interim Vice President for Research since January 1991, was appointed Vice President and Dean of Research. He continues his supervision of many of the university's major interdisciplinary research centers, as well as the Technology Licensing Office and, as dean, the Whitaker College of Health Sciences and Technology. He is a professor of physics and has served as director of the Francis Bitter National Magnet Laboratory.

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

Rafael L. Bras, Head, Department of Civil Engineering; Phillip L. Clay, Head, Department of Urban Studies and Planning; Stanley B. Kowalski, Director, Bates Linear Accelerator Center; Richard C. Larson, Co-director, Operations Research Center; Ronald M. Latanision, Chair, Council of Primary and Secondary Education; Steven R. Lerman, Director, Center for Educational Computing Initiatives; Kenneth A. Oye, Director, Center for International Studies; Robert P. Redwine, Director, Laboratory for Nuclear Science; Harriet Ritvo, Associate Dean, School of Humanities and Social Science; Richard J. Samuels, Head, Political Science; Yosef Sheffi, Director, Center for Transportation Studies; Merritt Roe Smith, Director, Program in Science, Technology and Society; John B. VanderSande, Associate Dean, School of Engineering; and William C. Wheaton, Director, Center for Real Estate.

Among key changes in the administration during the past year were the appointments of Sarah M. Carothers to Director of Development in the School of Science; Kathleen R. Cibotti as Director of Administrative Systems Development within Information Systems; John C. Crowley as Special Assistant to the President and Director of the MIT Washington Office; Gregory A. Jackson as MIT's first Director of Academic Computing; and Steven J. Marcus as the Editor in Chief of *Technology Review*. Also announced were the promotions of Stanley G. Hudson to Director of Student Financial Aid, and Donna M. Ticchi as Assistant Dean for Financial Administration within the School of Science.

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The honors and achievements of MIT faculty and staff are so numerous that, in this part of the report, I mention only some of the individual efforts and awards which have given such distinction to the Institute.

Under a new program named for the late Margaret L. A. MacVicar, MIT's first dean of undergraduate education – to honor her untiring efforts at MIT and nationally to enhance undergraduate education – six outstanding teachers were named MacVicar Faculty Fellows. This honor is in recognition of their exemplary and sustained contributions to undergraduate education. The first MacVicar Faculty Fellows (about six to eight are to be selected each year, with the program eventually supporting 60 to 80 fellows at one time) are: Professor Harold Abelson of the Department of Electrical Engineering and Computer Science; Professor Edward F. Crawley of the Department of Aeronautics and Astronautics; Professor Daniel S. Kemp of the Department of Chemistry; Professor Arthur P. Mattuck of the Department of Mathematics; Professor John B. Southard of the Department of Earth, Atmospheric, and Planetary Sciences and Professor Graham C. Walker of the Department of Biology.

Dr. Paul E. Gray, chairman of the MIT Corporation, received one of Japan's highest honors, the Imperial Decoration, Grand Cordon of the Order of the Sacred Treasure, on June 23, 1992. This recognition from the Emperor of Japan was for his efforts over the years to promote friendly relations and mutual understanding between the United States and Japan. Other members of the MIT community who have been similarly honored by Japan include Dr. Jerome B. Wiesner, Institute Professor and president emeritus, professor emeritus Samuel A. Goldblith, former vice president for resource development, and Dr. George H. Buchi, professor emeritus of organic chemistry.

President Bush awarded the National Medal of Science posthumously to Salvador Luria, Institute Professor emeritus and Nobel laureate, who died February 6, 1991. The award was for a lifetime devoted to applying genetics to viruses and bacteria, and for guiding the development of generations of students who have helped create the modern power of molecular biology.

President Emeritus Jerome B. Wiesner received the 1992 Vannevar Bush Award from the National Science Board, the policy-making body of the National Science Foundation. The Bush Award is given in recognition of outstanding contributions in science and technology that are significant to the welfare of mankind and the nation. Dr. Wiesner, a former science advisor to Presidents John F. Kennedy and Lyndon B. Johnson, has played a leading role in fostering public understanding of the risks of the nuclear age and in efforts to reduce those risks.

Two faculty members and a member of the research staff were elected to the National Academy of Engineering: Stanley Backer, professor emeritus and senior lecturer in the Department of Mechanical Engineering; Elisabeth M. Drake, associate director, MIT Energy Laboratory; and Robert S. Langer, Jr., Germeshausen Professor of Chemical and Biomedical Engineering, Department of Chemical Engineering. Their election brought to 106 the MIT membership in the NAE.

Eight faculty members were elected to the National Academy of Sciences: Jerome I. Friedman, Institute Professor and professor of physics; Robert G. Gallager, Fujitsu Professor of Electrical Engineering and codirector of the Laboratory for Information and Decision Systems; Henry W. Kendall, Julius A. Stratton Professor of Physics; Robert S. Langer, Germeshausen Professor of Chemical and Biomedical Engineering; George Lusztig, professor of mathematics; Robert D. MacPherson, professor of mathematics; Richard R. Schrock, Frederick G. Keyes Professor of Chemistry; JoAnne Stubbe, Ellen Swallow Richards Professor of Chemistry and professor of biology. The eight from MIT were the most from any university; their election brought to 96 the number of NAS members from MIT.

Ten MIT faculty members were elected as Fellows of the American Academy of Arts and Sciences: Professors George S. Boolos (Linguistics and Philosophy); H. Kent Bowen (Materials Science and Engineering); Sylvia T. Ceyer (Chemistry); Sallie W. Chisholm (Civil Engineering); Rudolph Jaenisch (Biology); Paul R. Krugman (Economics); Barbara H. Liskov (Electrical Engineering and Computer Science); Robert D. MacPherson (Mathematics); Robert Stalnaker (Linguistics and Philosophy) and Jack Wisdom (Earth, Atmospheric, and Planetary Sciences). Their election

brings to 219 the number of active and emeriti faculty members who are Academy Fellows.

Professor Paul R. Krugman of the Department of Economics received the John Bates Clark Medal, given biannually by the American Economic Association to the economist under 40 who has made the most important contributions to economics. Dr. Krugman has made important contributions in many areas, including both the microeconomics and macroeconomics of international relations.

Professor Peter S. Eagleson, recognized internationally for his work in hydrology and hydroclimatology, was selected as the 1992-93 recipient of the James R. Killian Jr. Faculty Achievement Award, which recognizes extraordinary professional accomplishments and service to MIT. The selection committee's citation noted that Dr. Eagleson "has led the extension of hydrology from the local into the regional and global scales."

Dr. Henry Jenkins, assistant professor of literature, was named the 1992 recipient of the Harold E. Edgerton Faculty Achievement Award, given annually to a junior faculty member in recognition of exceptional teaching, research, and scholarship. Professor Jenkins is a leader and founder of a new area of scholarship centered on the relation between the narrative arts and the mass media and their audiences.

* * *

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

Dr. Benjamin L. Averbach, professor of materials science and engineering, emeritus, died of cancer on April 1, 1992, at the age of 73. Dr. Averbach joined MIT in 1945 as a research assistant in what was then called the Department of Metallurgy and received the Sc.D. from MIT in 1947. An active and highly respected consultant with industry, he was involved with the development of new materials with high-fracture toughness for bearings used in high-speed aircraft engines and gears and in advances in magnetic and optical recording.

Yaichi Ayukawa, a Life Member of the MIT Corporation who worked tirelessly to build strong ties between the United States and his native Japan, died of a stroke on November 30, 1991. He was 68. Dr. Ayukawa received his S.M. in food technology from MIT in 1955 and the Ph.D. in food technology and industrial management in 1957. He served two five-year terms on the Corporation and was elected to Life Membership in 1987.

Dr. Alan H. Barrett, professor of physics, emeritus, died of cancer July 3, 1991, at the age of 64. He was widely known for his scientific contributions to the field of radio astronomy and to the radiometric study of the interstellar medium. Professor Barrett was an MIT faculty member from 1961 to his retirement in 1987.

William A. Coolidge, a philanthropist and corporate executive, died on May 24, 1992, at the age of 90. He was elected a term member of the Corporation in 1948 and a Life Member in 1953, becoming a Life Member Emeritus in 1976. He served 14 years as a

member of the Executive Committee. In recognition of his contributions to the Institute, one of the new West Campus Houses was named for him in 1977.

Dr. Daniel M. Holland, professor of finance, emeritus, at the Sloan School of Management and a widely known expert on taxation and public finance, died of a heart condition on December 15, 1991. He was 71. Professor Holland was an MIT faculty member from 1958 until his retirement in 1986, when he became an emeritus professor and senior lecturer. He also served as an assistant to the provost from 1986 to 1990.

Dr. Merrie G. Klapp, a research affiliate and former associate professor in urban studies and planning, died December 9, 1991 at the age of 41, of brain cancer. Her intellectual interests spanned the fields of architecture, mechanical engineering, semiotics, communications, environmental policy, and political science. Professor Klapp was appointed an assistant professor in 1982 and in 1989 became an associate professor.

Professor Margaret L. A. MacVicar, the educator and scientist who founded MIT's famous Undergraduate Research Opportunities Program (UROP), died September 30, 1991, after a year-long battle with cancer. She was 47. As MIT's first dean for undergraduate education, the position to which she was appointed in 1985 and held at her death, she headed the Institute's ongoing comprehensive review and restructuring of its undergraduate academic program. Dr. MacVicar came to MIT as a student in the fall of 1961, received the Sc.D. in metallurgy and materials science in 1967, and was appointed to the faculty in the Department of Physics in 1969. Professor MacVicar was known for her outstanding teaching and, in 1973, she was the first recipient of the Class of 1922 Career Development Award, endowed by class alumni to support young faculty members of exceptional promise and unusual devotion to teaching. In 1977, she received the Irwin Sizer Award for the most significant contribution to education at MIT. On the national scene, she provided leadership for a number of groups over the years, including serving as vice president of the Carnegie Institution, as a trustee of the Carnegie Foundation for the Advancement of Technology, and as a member of the Carnegie Council on Policy Studies in Higher Education.

Frank R. Milliken, Life Member Emeritus of the MIT Corporation and former head of the Kennecott Copper Corporation, died of a heart attack on December 4, 1991. He was 77. Mr. Milliken's association with the MIT Corporation began in 1954 when he became a member of the Visiting Committee for Geology and Geophysics. He was elected a member of the Corporation in 1962, became a Life Member in 1977, and, at his own request, transferred to Life Member Emeritus in 1986.

Dr. John C. Sheehan, professor of chemistry, emeritus, whose chemical synthesis of penicillin at MIT in 1957 led to the development of many tailor-made forms of the drug, died March 28, 1992, of congestive heart failure. He was 76. In 1946, he began a 31-year teaching career at MIT, eventually becoming professor of organic chemistry emeritus and senior lecturer in 1977. He was a scientific advisor to Presidents John Kennedy and Lyndon Johnson from 1961 to 1965, serving on a number of presidential advisory committees.

Robert C. Sprague, founder of the Sprague Electric Company, holder of the S.M. in naval architecture from MIT and a Life Member Emeritus of the MIT Corporation, died on September 27, 1991, at the age of 90. Mr. Sprague was first elected to the MIT Corporation in 1953, becoming a Life Member two years later and Life Member Emeritus in 1975. At various times he served on the executive committee, the membership committee, and the auditing committee, as well as chairing several visiting committees.

Dr. Bertram E. Warren, professor of physics, emeritus, died June 27, 1991, the day before his 89th birthday. He was recognized for his contributions to the science of using x-rays to study the structure of matter. Professor Warren earned three degrees from MIT. While studying for the Sc.D., which he received in 1929, he was appointed an instructor in the Department of Physics and remained a member of the department for his entire career. He became a full professor in 1939 and professor emeritus in 1967.

Edwin C. (Jack) Whitehead, founder of the MIT-affiliated Whitehead Institute for Biomedical Research and a Life Member of the MIT Corporation, died February 2, 1992, of a heart attack. He was 72. In 1982, Mr. Whitehead, a cofounder with his father of Technicon Corporation, a pioneer in scientific and clinical instrumentation, founded the Whitehead Institute, a nonprofit, independent basic research and teaching institution affiliated with MIT in its teaching activities but responsible for its own facilities and finances. In its short history, the Whitehead Institute has become one of the world's most prestigious and productive basic biological research organizations.

Dr. Hurd C. Willett, professor of meteorology, emeritus, renowned for his role in developing five-day weather forecasting techniques and widely known for his attempts at very-long-range forecasting, died on March 26, 1992. He was 89. Professor Willett, who joined the MIT staff in March 1929, specialized in climatic fluctuations and variable solar influences in his long-range forecasting. For several years, the press carried his annual predictions of what the weather would be over the next 12 months.

Dr. Glenn C. Williams, professor of chemical engineering, emeritus, died on July 2, 1991, of an aneurysm. He was 76. Dr. Williams began teaching at MIT in 1940, two years before receiving the Sc.D., and was an authority on missile propulsion. He headed MIT's Torpedo Fuel Laboratory during World War II, work that was recognized with the Navy Ordnance Development Award, and he later served as director of the MIT Fuels Research Laboratory. For many years he was the graduate officer of the Department of Chemical Engineering.

REGISTRATION

In 1991-92 student enrollment was 9,541, compared with 9,628 in 1990-91. There were 4,325 undergraduates (4,389 the previous year) and 5,216 graduate students (5,239 the previous year). The international student population was 2,117, representing 9 percent of the undergraduate and 33 percent of the graduate populations. These students were citizens of 103 countries. (Students with permanent residence status are included with US citizens.)

In 1991-92, there were 2,589 women students (1,433 undergraduate and 1,156 graduate) at the Institute, compared with 2,593 (1,451 undergraduate and 1,142 graduate) in 1990-91. In September 1991, 368 first-year women entered MIT, representing 35 percent of the freshman class of 1,053 students.

In 1991-92, there were, as self-reported by students, 2,052 minority students (1,643 undergraduate and 409 graduate) at the Institute, compared with 1,978 (1,582 undergraduate and 396 graduate) in 1990-91. Minority students included 347 African Americans (non-Hispanic), 34 Native Americans, 423 Hispanic Americans, and 1,248 Asian Americans. The first-year class entering in September 1991 included 457 minority students, representing 43 percent of the class.

DEGREES AWARDED

Degrees awarded by the Institute in 1991-92 included 1,039 bachelor's degrees, 1,137 master's degrees, 31 engineer's degrees, and 514 doctoral degrees – a total of 2,721 (compared with 2,771 in 1990-91).

STUDENT FINANCIAL AID

During the academic year 1991-92, the financial aid program reflected the increased need of undergraduate students. A total of 2,473 students who demonstrated need for assistance (56 percent of the enrollment) received $28,327,000 in grant aid and $10,278,000 in student loans from all sources. The total, $38,605,000, represents a 10 percent increase in aid compared to last year.

Grant assistance to undergraduates was provided by $8,475,000 in income from the scholarship endowment; $859,000 in outside gifts; federal grants (including ROTC scholarships) totaling $3,151,000; and $2,072,000 in direct grants from non-federal outside sources to needy students. In addition, $13,769,000 in scholarships from MIT's unrestricted funds was provided to undergraduates, inclusive of the special program of scholarship aid to needy minority group students, which represented $275,000, and the MIT Opportunity Awards, which accounted for $928,000. An additional 452 students received grants irrespective of need from outside agencies totaling $2,088,000. The undergraduate scholarship endowment was increased by the addition of $6,582,000 in new funds (more than last year's increase), raising the principal of the endowment by 10 percent to $75,090,000.

Loans totaling $9,619,000 were made to undergraduates, a 6 percent increase from last year. Of this amount $1,291,000 came from the Technology Loan Fund, $2,856,000 from the Perkins Loan Program, and $5,472,000 from the state-administrated Stafford Guaranteed Loan Programs and other outside sources.

Graduate students obtained $2,570,000 from the Technology Loan Fund. In addition, $841,000 was loaned by MIT under the Stafford Guaranteed Student Loan Program. The total, $3,411,000, represents a 9 percent increase over last year's level. Graduate students obtained $3,853,000 from outside sources under the Stafford Guaranteed Student Loan Program, 10 percent more than last year, and $121,000 from federal Supplemental Student Loans. Graduate students also received $1,536,000 in Perkins Loan funds.

The total amount of loans made to undergraduate and graduate students was $18,540,000, a 9.2 percent increase over last year.

For the first time in many years, the number of needy undergraduate students receiving aid decreased slightly. The average need, however, increased – reflecting, in part, the higher proportion of students from low income families. This year the percentage of freshmen coming from the lowest national income quartile was 23 percent, the largest proportion ever. In addition, the financial aid program funded the higher need of families as the recession deepened and unemployment increased.

The total need for financial aid for undergraduates was $41,639,000. The average need for aid rose by 8.3 percent to $16,765. In the aggregate, the financial aid program required $19,427,000 from needy students' family resources, and provided $41,639,000 in aid dollars. As in years past, the aid program accounted for two-thirds of needy students' total costs.

CAREER SERVICES AND PREPROFESSIONAL ADVISING

For the second year in a row, the economic climate was not promising for graduating students entering the job market, or for students looking for summer jobs. The number of employers recruiting through the Careers Office totaled 371, a fraction less than last year's figure, which was down 20 percent from 1989-90. Nevertheless, as in previous recessions, MIT job seekers generally fared remarkably well. This was especially true of students in engineering and management. They continued to find good summer jobs and good jobs at graduation. Students in other disciplines felt the bite more sharply. The last two years have been difficult for graduates in architecture and urban studies, and the market has been extremely tight for Ph.D.'s in mathematics and physics hoping for jobs in academia.

Salary offers in most fields moved up at less than the inflation rate. Students enjoying the largest gains were S.B.'s in chemical engineering, who received offers 7 percent higher than the year before; S.M.'s in mechanical engineering, who received offers nearly 8 percent higher; and Ph.D.'s in electrical engineering, who found industry willing to make offers 15 percent higher.

There was a jump in the number of MIT applicants to medical school, paralleling an increase in the nation at large. Preliminary data show 131 MIT candidates, up from 119 at the same time last year. This year's candidates included 91 undergraduates, 2

graduate students, and 38 alumni. Of the undergraduates, 44, or very nearly half, were women; the graduate student and alumni candidates were divided exactly (20/20) between men and women. There was the same equal balance between men and women in 1991, when 83 percent of the women were accepted and 77 percent of the men. The increasing number of candidates in the nation at large has increased the odds a bit, but MIT's candidates are again likely to have done well.

GIFTS

Gifts, grants, and bequests to MIT from private donors in 1991-92 totaled $97.1 million. This amount includes cash, securities, and real estate gifts totaling $89.9 million, and $7.2 million of equipment gifts. The gifts reported by the Alumni Fund increased by 13.2 percent to a new record of $17.1 million. This amount was more than twice the total just ten years ago.

The *Campaign for the future* reached a successful conclusion at fiscal year end. The campaign total of $710 million exceeded the original goal set five years ago by 29 percent and exceeded the new goal set 28 months ago by $10 million. During the year, the campaign total of gifts and pledges increased by $105 million as new pledges increased by more than payments toward outstanding pledges. 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 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 by the Treasurer, the total financial operations of the Institute, including sponsored research, amounted to $1.08 billion – a decrease of 0.2 percent from 1990-91. Education and general expenses – excluding the direct expenses of departmental and interdepartmental research and the Lincoln Laboratory – amounted to $509.7 million during 1991-92, compared with $488.5 million in 1990-91. The direct expenses of departmental and interdepartmental sponsored research on campus increased from $229.4 million to $231.5 million, and direct expenses of the Lincoln Laboratory's sponsored research decreased from $367.7 million to $342.1 million. Current revenues used to meet the Institute's operating expenses totaled $1.07 billion, augmented by $6.8 million in current gifts and $6.3 million of other fund balances.

At the end of the 1992 fiscal year, the Institute's investments, excluding retirement funds, student notes receivable, and amounts due from educational plant, had a book value of $1.5 billion and a market value of $1.95 billion, compared to last year's book value of $1.4 billion and market value of $1.77 billion.

PHYSICAL PLANT AND CAMPUS ENVIRONMENT

Conservation of resources continues to be a major focus at the Institute. During the year, MIT joined the Environmental Protection Agency's Green Lights Program, which is aimed at reducing air pollution caused by emissions from electric-generating plants by reducing the overall demand for electricity. By joining this

program, the Institute has committed to installing energy efficient lighting in 90 percent of its buildings, where it is cost effective, over the next five-year period.

In other conservation efforts, several water-saving initiatives were implemented this year, including the elimination of once-through cooling systems and the limited use of water from the Charles River for irrigation purposes. As a result of these and future efforts, the Institute should realize a 25 percent reduction in water usage.

Progress continues on the construction of the Biology Building. The foundation was completed in late spring and work on the superstructure was underway at year's end. A 6,000 square-foot addition to Haystack Observatory was completed during the year, as was the total renovation of a property at 477-479 Commonwealth Avenue in Boston, which now houses 60 members of the Alpha Phi Sorority. Other major design and construction activities that took place during the year included a continuation of work at the former Cabot Building (Building E56) in the areas that will house the Dibner Institute and Burndy Library, and the permitting and design efforts on the proposed combined-cycle cogeneration project. The actual environmental permit for the cogeneration plant was received early in the spring. Major maintenance activities completed during the year included reconstruction of the concrete plaza surrounding the Compton Building (Building 26) and replacement of the roofing system on Building 1.

Issues associated with ever-increasing regulatory requirements regarding the environment, health, and safety continue to necessitate close monitoring to ensure that the Institute remains in compliance. As a result of recent passage of the Americans with Disabilities Act (ADA), which requires that any employer with 15 or more employees provide reasonable access for handicapped individuals, the Institute has established a committee to identify locations where access is difficult and make recommendations for overcoming the problems.

REFERENCES

Resources used in preparing the president's essay included the Caspar Database of the National Science Foundation; *Science and Engineering Indicators*, 1991 Edition, National Science Board; *Science and Technology in the Academic Enterprise: Status, Trends and Issues.* October 1989; *Higher Education in a Changing Economy,* edited by K. H. Hanson and J. W. Meyerson, American Council on Education, 1990; *Inflation Measures for Schools and Colleges, 1991 Update,* Research Associates of Washington; *Higher Education Revenues and Expenditures, Institutional Data FY1990,* Research Associates of Washington; *Trends in Student Aid 1982-1992*, College Board; *Campus Trends 1992,* edited by Elaine El-Khawas, Higher Education Panel Report Number 82, July 1992, American Council on Education.

Personnel Changes

CORPORATION

DEATHS

Yaichi Ayukawa
Life Member

William A. Coolidge
Life Member, Emeritus

Frank R. Milliken
Life Member, Emeritus

Robert C. Sprague
Life Member, Emeritus

Edwin C. Whitehead
Life Member

CHANGES OF APPOINTMENT

Jerry McAfee
Life Member, Emeritus

Harold J. Muckley
Life Member, Emeritus

ELECTIONS

Pedro Aspe Armella
Member

Gerald J. Burnett
Member

George N. Hatsopoulos
Member

Robert B. Horton
Member

Shirley A. Jackson
Life Member

Nannerl O. Keohane
Member

William B. Lenoir
Member

Robert M. Metcalfe
Member

Dava J. Newman
Member

Frank Press
Life Member

Romano Prodi
Member

MEMBERS EX-OFFICIO

Robert V. Antonucci
Commissioner of Education

Robert A. Muh
President
Alumni Association

TERMS EXPIRED

John K. Castle
Member

Walter J. Humann
Member

F. Richard Meyer, III
Member

Rita A. O'Brien
Member

Robin M. Wagner
Member

FACULTY

DEATHS

Martin A. Abkowitz
Department of Ocean Engineering

Benjamin L. Averbach
Department of Materials Science and Engineering

Margaret L. A. Mac Vicar
Office of the Provost

John C. Sheehan
Department of Chemistry

RETIREMENTS

Nesmith C. Ankeny
Professor
Department of Mathematics

Gordon L. Brownell
Professor
Department of Nuclear Engineering

Peter Elias
Professor
Department of Electrical Engineering and Computer Science

Lawrence B. Evans
Professor
Department of Chemical Engineering

Imre Halasz
Professor
Department of Architecture

Frank S. Jones
Professor
Department of Urban Studies and Planning

Robert E. Jones
Professor
Foreign Languages and Literatures Section

Julian Keilson
Adjunct Professor
Sloan School of Management

H. Gobind Khorana
Professor
Department of Biology

Thomas S. Kuhn
Professor
Department of Linguistics and Philosophy

Patrick Leehey
Professor
Department of Mechanical Engineering

Francis E. Low
Institute Professor

Robert W. Mann
Professor
Department of Mechanical Engineering

Lucian W. Pye
Professor
Department of Political Science

Charles N. Satterfield
Professor
Department of Chemical Engineering

Donald A. Schon
Professor
Department of Urban Studies and Planning

Maurice K. Smith
Professor
Department of Architecture

David C. White
Professor
Department of Electrical Engineering and Computer Science

RESIGNATIONS

Professor

K. Barry Sharpless
Department of Chemistry

Associate Professor

David J. Anick
Department of Mathematics

Richard C. Celotto
Department of Ocean Engineering

Kenneth A. Froot
Sloan School of Management

L. Gregor Herten
Department of Physics

Ellen Hildreth
Department of Brain and Cognitive Sciences

Robert J. Ledoux
Department of Physics

Donald C. Rio
Department of Biology

H. Earl Ruley
Department of Biology

Keith D. Stolzenbach
Department of Civil Engineering

Lloyd N. Trefethen
Department of Mathematics

Andreas Hubertus Vonflotow
Department of Aeronautics and Astronautics

Assistant Professor

Karyn A. Altman
Athletic Department

Jeffrey L. Feerer
Department of Chemical Engineering

Nicole Herbots
Department of Materials Science and Engineering

Paul Hoffman
Department of Linguistics and Philosophy

Maryellen C. MacDonald
Department of Brain and Cognitive Sciences

Frank C. Miller
Department of Architecture

Danny Quah
Department of Economics

Andrea Shepard
Department of Economics

Hee-Sup Shin
Department of Biology

Thomas Simmons
Program in Writing and Humanistic Studies

Paul A. Webley
Department of Chemical Engineering

PROMOTIONS

To Professor

Harold Abelson
Department of Electrical Engineering and Computer Science

Triantaphyllos R. Akylas
Department of Mechanical Engineering

Boris Altshuler
Department of Physics

Timothy L. Grove
Department of Earth, Atmospheric, and Planetary Sciences

Leonard P. Guarente
Department of Biology

Harold F. Hemond
Department of Civil Engineering

Michael J. Hopkins
Department of Mathematics

Sandra C. Howell
Department of Architecture

Pierre A. Humblet
Department of Electrical Engineering and Computer Science

Monty Krieger
Department of Biology

Jeffrey H. Lang
Department of Electrical Engineering and Computer Science

Tomas Lozano-Perez
Department of Electrical Engineering and Computer Science

Silvio Micali
Department of Electrical Engineering and Computer Science

Richard C. Mulligan
Department of Biology

Paul Osterman
Sloan School of Management

Anthony T. Patera
Department of Mechanical Engineering

Barry R. Posen
Department of Political Science

Sherry R. Turkle
Program in Science, Technology, and Society

Jack Wisdom
Department of Earth, Atmospheric, and Planetary Sciences

To Associate Professor

Edith K. E. Ackermann
Media Arts and Sciences Section

Edmund W. Bertschinger
Department of Physics

Richard P. Binzel
Department of Earth, Atmospheric, and Planetary Sciences

David Owen Brink
Department of Linguistics and Philosophy

Stuart Brown
Department of Materials Science and Engineering

Michael A. Cusumano
Sloan School of Management

Munther A. Dahleh
Department of Electrical Engineering and Computer Science

Jesus A. del Alamo
Department of Electrical Engineering and Computer Science

Mark Drela
Department of Aeronautics and Astronautics

Jonathan A. Fox
Department of Political Science

John P. Grotzinger
Department of Earth, Atmospheric, and Planetary Sciences

Steven R. Hall
Department of Aeronautics and Astronautics

Ellen M. Immergut
Department of Political Science

John H. Lienhard, V
Department of Mechanical Engineering

Emanuel M. Sachs
Department of Mechanical Engineering

Nathan O. Siu
Department of Nuclear Engineering

Lawrence M. Wein
Sloan School of Management

Jacob K. White
Department of Electrical Engineering and Computer Science

CHANGES OF APPOINTMENT

Stanford Anderson
Department Head and Professor
Department of Architecture

Anuradha Annaswamy
Hatsopoulos Career Development Assistant Professor
Department of Mechanical Engineering

Arvind
Charles W. and Jennifer C. Johnson Professor of Computer Science and Engineering
Department of Electrical Engineering and Computer Science

Lotte L. Bailyn
T. Wilson (1953) Professor in Management
Sloan School of Management

Peter P. Belobaba
Charles Stark Draper Assistant Professor
Department of Aeronautics and Astronautics

Robert J. Birgeneau
Dean of the School of Science and
Cecil and Ida Green Professor of Physics

V. Michael Bove
Sony Corporation Career Development Assistant Professor of Media Technology
Media Arts and Sciences Section

Kenneth S. Breuer
Charles Stark Draper Assistant Professor of Aeronautics and Astronautics
Department of Aeronautics and Astronautics

Robert A. Brown
Department Head and Warren K. Lewis Professor of Chemical Engineering
Department of Chemical Engineering

Gerbrand Ceder
Alcoa Assistant Professor of Materials Science and Engineering
Department of Materials Science and Engineering

Sylvia T. Ceyer
W. M. Keck Foundation Professor of Energy
Department of Chemistry

Mikhail Choubine
Visiting Professor
Department of Mathematics

Renee Y. Chow
Assistant Professor
Department of Architecture

Jung-Hoon Chun
Esther and Harold E. Edgerton Assistant Professor
Department of Mechanical Engineering

James E. Chung
Analog Devices Career Development Assistant Professor of Electrical Engineering
Department of Electrical Engineering and Computer Science

Linda G. Cima
Henry L. Doherty Assistant Professor in Ocean Utilization
Department of Chemical Engineering

Don F. Clausing
Bernard M. Gordon Adjunct Professor of Engineering Innovation and Practice
Department of Electrical Engineering and Computer Science

Janet Currie
Pentti J. K. Kouri
Career Development
Assistant Professor
Department of Economics

Peter Diamond
Paul A. Samuelson
Professor of Economics
Department of Economics

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

David C. Dunand
AMAX Assistant Professor
of Materials Engineering
Department of Materials
Science and Engineering

Thomas W. Eagar
Director,
Materials Processing Center
and Richard P. Simmons
Professor of Metallurgy
Department of Materials
Science and Engineering

Dara Entekhabi
Assistant Professor
Department of Civil
Engineering

Stanley Fischer
Elizabeth and James Killian
Professor
Department of Economics

Douglas Forsyth
Class of 1942 Career
Development Assistant
Professor in Humanities
History Section

J. Robert Fricke
Assistant Professor
Department of Ocean
Engineering

Jerome I. Friedman
Institute Professor

Naomi K. Fukagawa
Assistant Professor
Harvard-MIT Division of
Health Sciences and
Technology

Karen K. Gleason
Esther and Harold E.
Edgerton
Assistant Professor of
Chemical Engineering
Department of Chemical
Engineering

Jerry Hausman
John and Jennie S. MacDonald
Professor of Economics
Department of Economics

Irene R. Heim
Class of 1943 Career
Development Associate
Professor
Department of Linguistics
and Philosophy

John B. Heywood
Co-Director, Leaders for
Manufacturing Program and
Professor of Mechanical
Engineering
Department of Mechanical
Engineering

Qing Hu
KDD Career Development
Assistant Professor of
Electrical Engineering
Department of Electrical
Engineering and
Computer Science

Chi-Fu Huang
J. C. Penney Professor
Sloan School
of Management

Richard O. Hynes
Director,
Center for Cancer Research
and Professor of Biology

Ellen M. Immergut
Ford International Career
Development Associate
Professor
Department of
Political Science

Xiangdong Ji
Assistant Professor
of Physics
Department of Physics

John Kassakian
Professor of Electrical
Engineering and Director,
Laboratory for
Electromagnetic and
Electronic Systems

Samuel J. Keyser
Peter de Florez Professor,
Professor of Linguistics,
and Associate Provost for
Institute Life

Masood A. Khan
Visiting Associate Professor
Department of Architecture

Philip S. Khoury
Dean of the School
of Humanities and Social
Science and Professor of
History

Kirk D. Kolenbrander
Carl Richard Soderberg
Assistant Professor of
Electronic Materials
Department of Materials
Science and Engineering

Leslie A. Kolodziejski
Karl R. Van Tassel
Career Development
Assistant Professor of
Electrical Engineering
Department of Electrical
Engineering and
Computer Science

Stanley B. Kowalski
Director,
Bates Linear Accelerator
and Professor of Physics
Department of Physics

Harri Kytomaa
Henry L. Doherty
Assistant Professor
in Ocean Utilization
Department of Mechanical
Engineering

Peter T. Lansbury, Jr.
Firmenich Career
Development Assistant
Professor
Department of Chemistry

Steven R. Lerman
Class of 1922 Professor
and Director, Center for
Educational Computing
Initiatives
Department of Civil
Engineering

Ronald B. Lewcock
Visiting Professor
Department of Architecture

Alan P. Lightman
Section Head of the Program
in Writing and Humanistic
Studies and Professor of
Science and Writing

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

Patricia E. Maes
Assistant Professor
of Media Technology
Media Arts and Sciences
Section

Kenneth R. Manning
Thomas Meloy
Professor of Rhetoric
Program in Writing
and Humanistic Studies

Borivoje Mikic
Associate Head and
Professor
Department of Mechanical
Engineering

Ernest Moniz
Department Head
and Professor
Department of Physics

Daniel N. Osherson
Visiting Professor
Department of Brain
and Cognitive Sciences

Gregory M. Papadopoulos
Class of 1922 Career
Development Assistant
Professor of Electrical
Engineering and Computer
Science
Department of Electrical
Engineering and
Computer Science

Michael J. Piore
David W. Skinner Professor
and Professor of Economics
and Management
Department of Economics

Julias Rebek, Jr.
Camille Dreyfus Professor
Department of Chemistry

Wellington Reiter
Assistant Professor
Department of Architecture

Martin A. Schmidt
Carl Richard Soderberg
Assistant Professor in
Power Engineering
Department of Electrical
Engineering and
Computer Science

Phillip A. Sharp
Department Head
and Professor
Department of Biology

Yosef Sheffi
Director,
Center for Transportation
Studies and Professor of
Civil Engineering

Alexander Slocum
Flowers Career
Development
Assistant Professor
Department of Mechanical
Engineering

Arthur C. Smith
Dean for Undergraduate
Education and Student
Affairs and Professor of
Electrical Engineering

Joseph L. Smith, Jr.
Ford Professor
of Engineering
Department of Mechanical
Engineering

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

Gerald J. Sussman
Matsushita Professor of
Electrical Engineering
Department of Electrical
Engineering and
Computer Science

Joseph M. Sussman
J. R. East Professor
of Civil Engineering
Department of Civil
Engineering

Judith J. Thomson
Laurance S. Rockefeller
Professor of Philosophy
Department of Linguistics
and Philosophy

Harry L. Tuller
Sumitomo Electric Industries
Professor of Engineering
Department of Materials
Science and Engineering

John B. Vander Sande
Cecil and Ida Green
Distinguished Professor
Department of Materials
Science and Engineering

Ian Waitz
Rockwell International
Career Development
Assistant Professor
Department of Aeronautics
and Astronautics

Andrew J. Whittle
Gilbert W. Winslow
Career Development
Assistant Professor
Department of Civil
Engineering

Sheila Widnall
Abby Rockefeller Mauze
Professor of Aeronautics
and Astronautics and
Associate Provost

John R. Williams
Gilbert W. Winslow
Career Development
Associate Professor
Department of Civil
Engineering

James H. Williams, Jr.
School of Engineering
Professor in Teaching
Excellence
Department of Mechanical
Engineering

James R. Williamson
Pfizer-Laubach Career
Development Assistant
Professor
Department of Chemistry

Elizabeth A. Wood
Assistant Professor
History Section

JoAnne Yates
Associate Professor
of Management
Sloan School
of Management

NEW APPOINTMENTS

Professor

Michael Dennis
Professor
Department of Architecture

John W. Dower
Professor
History Section

Alexander Keyssar
Professor
History Section

Shigeru Miyagawa
Professor
Foreign Languages
and Literatures Section

Hidde Ploegh
Professor
Department of Biology and
Center for Cancer Research

Associate Professor

John C. Marshall
Associate Professor
Department of Earth,
Atmospheric, and
Planetary Sciences

Drazen Prelec
Associate Professor
of Marketing
Sloan School
of Management

Roy J. Strickland
Associate Professor
Department of Architecture

Assistant Professor

Christian G. Appy
Assistant Professor
in Humanities
History Section

Andrew B. Bernard
Assistant Professor
Department of Economics

Aaron F. Bobick
Assistant Professor
of Media Technology
Media Arts and Sciences
Section

Sibel Bozdogan
Assistant Professor
Department of Architecture

Geoffrey M. Brooke
Assistant Professor
of Management Science
Sloan School
of Management

Gerbrand Ceder
Assistant Professor
Department of Materials
Science and Engineering

Peter C. Dedon
Assistant Professor
of Toxicology
Division of Toxicology

David Genesove
Assistant Professor
of Economics
Department of Economics

Nesbitt W. Hagood
Charles Stark Draper
Assistant Professor of
Aeronautics and
Astronautics
Department of Aeronautics
and Astronautics

Tyler E. Jacks
Assistant Professor
Department of Biology and
Center for Cancer Research

Barry S. Johnston
Assistant Professor
Department of Chemical
Engineering

Robin W. Kilson
Assistant Professor
in Humanities
History Section

Jon E. Lendon
Assistant Professor
History Section

Leonid Levitov
Assistant Professor
of Physics
Department of Physics

Samir D. Mathur
Assistant Professor
of Physics
Department of Physics

Mark Matthews
Assistant Professor
of Applied Mathematics
Department of Mathematics

Anne E. McCants
Assistant Professor
in Humanities
History Section

James D. Paduano
Charles Stark Draper
Assistant Professor
Department of Aeronautics
and Astronautics

Rosalind W. Picard
Assistant Professor
of Media Technology
Media Arts and Sciences
Section

Lisa J. Randall
Assistant Professor
of Physics
Department of Physics

Gregory C. Rutledge
Texaco-Mangelsdorf
Assistant Professor of
Chemical Engineering
Department of Chemical
Engineering

Maureen A. Scully
Assistant Professor
of Management
Sloan School
of Management

Scott A. Simonson
Assistant Professor
Department of Nuclear Engineering

Lones A. Smith
Assistant Professor
of Economics
Department of Economics

Paraskevas Sphicas
Assistant Professor
of Physics
Department of Physics

Mark F. Sylvester
Assistant Professor
Department of Mechanical Engineering

Ian Waitz
Charles Stark Draper
Assistant Professor of
Aeronautics and Astronautics
Department of Aeronautics and Astronautics

Xiao-Gang Wen
Assistant Professor
of Physics
Department of Physics

Gregory W. Wornell
Assistant Professor
of Electrical Engineering
Department of Electrical Engineering and Computer Science

Bin Zhou
Assistant Professor
of Management Science
Sloan School
of Management

Adjunct Professor

Lawrence B. Evans
Adjunct Professor
Department of Chemical Engineering

Visiting Professor

Dalia Atlas
Visiting Professor
in Humanities
Music and Theater Arts Section

Elwyn Berlekamp
Visiting Professor
Department of Electrical Engineering and Computer Science

Peter C. Breedveld
Visiting Professor
Department of Mechanical Engineering

Michael Bruno
Visiting Professor
of Economics
Department of Economics

Dennis R. Capozza
Visiting Professor
Department of Urban Studies and Planning

Y. Austin Chang
Visiting Professor
Department of Materials Science and Engineering

Kuo-Chih Chou
Visiting Professor
Department of Materials Science and Engineering

Andre Clement
Visiting Professor
Department of Ocean Engineering

Nicholas A. Cumpsty
Jerome C. Hunsaker
Visiting Professor of
Aeronautics and Astronautics
Department of Aeronautics and Astronautics

Edward L. Cussler
Visiting Professor
Department of Chemical Engineering

Reiner Decher
Visiting Professor
Department of Aeronautics and Astronautics

William G. Dwyer
Visiting Professor
Department of Mathematics

Ivan Egry
Visiting Professor
Department of Materials Science and Engineering

Nicolas L Enstathopoulos
Visiting Professor
Department of Materials Science and Engineering

Klaus Herdeg
Visiting Professor
Department of Architecture

Barbara Bund Jackson
Visiting Professor
of Management Science
Sloan School
of Management

James P. Johnston
Visiting Professor
Department of Aeronautics and Astronautics

Thomas Kailath
Visiting Professor
of Electrical Engineering and
Senior Vinton Hayes Fellow
Department of Electrical Engineering and Computer Science

Narendra K. Karmarker
Visiting Professor
of Applied Mathematics
Department of Mathematics

Ira Katznelson
Visiting Professor
Department of
Political Science

Yoshimasa Kyogoku
Visiting Professor
Department of Biology

Royston Landau
Visiting Professor
Department of Architecture

Brigitte D. Lane
Visiting Professor
Foreign Languages and Literatures Section

Baldwin S. Lee
Visiting Professor
Department of Architecture

Michael Magazine
Visiting Professor
of Management Science
Sloan School
of Management

Menachim Magidor
Visiting Professor
Department of Mathematics

Shlomo Maital
Visiting Professor
Sloan School
of Management

Everett Mendelsohn
Visiting Professor
Program in Science, Technology, and Society

Alan Needleman
Visiting Professor
Department of Mechanical Engineering

James F. O'Gorman
Visiting Professor
Department of Architecture

Kwang-Chun Park
Visiting Professor
Department of Aeronautics and Astronautics

Robert Porter
Visiting Professor
of Economics
Department of Economics

Daniel G. Quillen
Visiting Professor
Department of Mathematics

Alexander Razborov
Visiting Professor
Department of Mathematics

Alfred Schneider
Visiting Professor
Department of Nuclear Engineering

Shoji Shiba
Visiting Professor
Sloan School
of Management

Sven Treitel
Visiting Professor
Department of Earth, Atmospheric, and Planetary Sciences

Robert Wade
Visiting Professor
Sloan School
of Management

Stanley I. Weiss
Jerome C. Hunsaker
Visiting Professor of
Aeronautics and Astronautics
Department of Aeronautics and Astronautics

David C. Wharton
Visiting Professor
Department of Biology

Akiva M. Yaglom
Visiting Professor
Department of Aeronautics and Astronautics

Visiting Associate Professor

Ella Louise Bell
Visiting Associate
Professor
Sloan School
of Management

Eng-Soon Chan
Visiting Associate Professor
Department of Civil Engineering

Stephen Crain
Visiting Associate Professor
Department of Brain and Cognitive Sciences

Robert D'Andrea
Visiting Associate Professor
Department of Civil Engineering

James Allen Fill
Visiting Associate Professor
Department of Mathematics

David Finch
Visiting Associate Professor
Naval Science

Masashi Kashiwagi
Visiting Associate Professor
Department of Ocean Engineering

Janice A. Klein
Visiting Associate Professor
of Management
Sloan School of Management

Kala Krishna
Visiting Associate Professor
Department of Economics

Robert W. Lawler
Visiting Associate Professor
Media Arts and Sciences Section

Alfred A. Marcus
Visiting Associate Professor
of Management
Sloan School of Management

Spyridon A. Mavrakos
Visiting Associate Professor
Department of Ocean Engineering

Michelle Millar
Visiting Associate Professor
Department of Chemistry

Akos Moravanszky
Visiting Associate Professor
Department of Architecture

Barbara A. Osborne
Visiting Associate Professor
Department of Biology

Roger P. Simmonds
Visiting Associate Professor
Department of Urban Studies and Planning

Alok Sinha
Visiting Associate Professor
Department of Aeronautics and Astronautics

Deborah Smiley
Visiting Associate Professor
Media Arts and Sciences Section

Jeannette M. Wing
Visiting Associate Professor
Department of Electrical Engineering and Computer Science

Visiting Assistant Professor

Obrad Babic
Visiting Assistant Professor
Department of Aeronautics and Astronautics

Smadar Cohen
Visiting Assistant Professor
Department of Biology

Olga N. Danilevskaya
Visiting Assistant Professor
Department of Biology

Helen Dunstan
Visiting Assistant Professor
in Humanities
History Section

James F. Gammill
Visiting Assistant Professor
of Management
Sloan School of Management

David K. Goldstein
Visiting Assistant Professor
Sloan School of Management

Mauro F. Guillen
Visiting Assistant Professor
Sloan School of Management

Hilde Heynen
Visiting Assistant Professor
Department of Architecture

C. Shayne O'Neil
Visiting Assistant Professor
Department of Architecture

Connie P. Ozawa
Visiting Assistant Professor
of Management
Sloan School of Management

Robin Ann Prager
Visiting Assistant Professor
of Management
Sloan School of Management

Klaus M. Schmidt
Visiting Assistant Professor
of Economics
Department of Economics

Marc Swetlitz
Visiting Assistant Professor
of the History of Science
Program in Science, Technology, and Society

Yih-jian Tai
Visiting Assistant Professor
in Humanities
Foreign Languages and Literatures Section

ADMINISTRATION

DEATHS

Wade L. Wilson
Administrative Staff
Lincoln Laboratory

RETIREMENTS

John J. Barbato
Project and Construction Engineer
Physical Plant

Robert S. Berg
Administrative Staff
Lincoln Laboratory

John C. Berlinguet, Jr.
Superintendent of Support Services and Building Maintenance
Physical Plant

James W. Coleman
Director
Graphic Arts

Peter H. Flagg
Area Manager
Administrative Systems Development

Leonard V. Gallagher
Director of Student Financial Aid
Student Financial Aid Office

Edward J. Gaudiano
Facilities Officer
Department of Electrical Engineering and Computer Science

Haig G. Gechijian
Senior Mechanical Engineer
Physical Plant

Norma M. Gicka
Accounting Analyst
Sloan School of Management

Mary J. Gulino
Assistant Director
Office of Campaign Systems

Ralph V. Jackson
Route Supervisor, Building Services
Physical Plant

Michael J. Karaffa
Manager, Physical Plant Operations, LINAC
Physical Plant

John J. Laplume
Engineering Assistant
Physical Plant

Andrew M. MacDougall, Jr.
Manager of Engineering
Physical Plant

William M. Malone
Facilities Manager
Athletic Department

Angelo A. Manganaro
Administrative Staff
Lincoln Laboratory

Carol Ann McIntire
Administrative Assistant
Department of Civil Engineering

Edward D. McNulty
Lieutenant
Campus Police

Ralph D. McPherson
Administrative Staff
Lincoln Laboratory

Helen I. Osborne
Managing Editor
MIT Press

Antero Severino
Administrative Staff
Lincoln Laboratory

Murray L. Somerville
Supervisor of Support Facilities
Department of Chemistry

John H. Stowe
Supervisor, Mechanical Services
Physical Plant

Kenneth L. Thompson
Project Manager
Physical Plant

RESIGNATIONS

Omar Abuhasan
Analyst Programmer
Administrative Systems Development

Leah Anderson
Administrative Officer
Department of Political Science

Susan L. Anderson
Area Director
Alumni Association

Judith A. Bellamari
Senior Applications Coordinator
Office of Facilities Management Systems

Andrew Bennett
Consultant
Distributed Computing and Network Services

Leslie Wolff Borak
Area Director
Alumni Association

Mary Lou Boutwell
Associate Director
Center for Real Estate Development

Cathy H. Brown
Coordinator, General Gifts Solicitation/Alumni Fund
Alumni Association

Elaine M. Bullen
Staff Administrator
Administrative Systems Development

Charles R. Carr
Senior Research Analyst, Resource Development
Office of Campaign Systems

Naomi F. Chase
Staff Writer/Editor
Public Relations Services

Richard Cooper
Analyst Programmer
Administrative Systems Development

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

Susan Deford-Offner
Assistant Treasurer, Investments/
Assistant Director, Real Estate
Treasurer's Office

Leslie M. Denis
Budget Officer
Office of Financial Planning and Management

Nanci A. Drago
Assistant Manager, Quarter Century Club
Office of Special Community Services

Julie A. Eastman
Assistant Director
Director, Major Gifts

James W. Emmett
Credit and Collection Manager
MIT Press

John William Gettens
Analyst Programmer
Distributed Computing and Network Services

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

Lore A. Greene
Coordinator, Graduate Alumni Programs
Alumni Association

Frederick P. Gross
Director of Corporate Development
Vice President, Resource Development

Maria I. Hecht
Publications Coordinator
Office of the Summer Session

Deborah Herman
Assistant to the Dean
Dean for Student Affairs

Lisa H. Hiley
Assistant Director
Office of Foundation Relations

Susanna C. Hinds
Director of Student Activities
Dean for Student Affairs

Joan M. Hutchins
Financial Administrator
Department of Chemistry

John L. Kenney
Coordinator for Donor Relations
Sloan School of Management

Anna M. Koch
Librarian
Libraries

John P. Langowski, Jr.
Analyst Programmer
Administrative Systems Development

Michael G. Larivee
Systems Programmer
Distributed Computing and Network Services

Ching-Chuan Aida Liu
Consultant
Computing Support Services

Maryann S. Lord
Administrator for Graduate Student Affairs
Department of Political Science

Kathleen L. Marshall
Assistant to the Executive Director
Medical Department

Sandra L. Maxfield
Associate Head Librarian, Engineering and Science Libraries

Sarah McConville
Publicity Manager
MIT Press

Branger Miller
Major Gifts Officer
Director, Major Gifts

Lucia L. Miller
Journals Marketing Manager
MIT Press

Marc S. Miller
Senior Editor, National Pages, *Technology Review*
Alumni Association

Kimberly Miner
Electronic Publishing Coordinator
Sloan School of Management

Michael J. Norton, Jr.
Lieutenant
Campus Police

Kimberly Ann O'Brion
Administrative Assistant
Athletic Department

Catherine Ormond
Administrative Officer
Department of Physics

James A. Paterson
Senior Research Analyst, Resource Development
Office of Development Services

Graciela Perez-Trevisan
Coordinator, Women's Studies
School of Humanities and Social Science

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

Laura L. Quinn
District Director
Director, Major Gifts

Jodi Rafus
Coordinator, Direct Mail Program
Alumni Association

Peter A. Richards
Licensing Associate
Technology Licensing Office

Laura G. Royer
Supervisor, Circulation Services
Libraries

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

Tracy A. Springer
Benefits Counselor
Personnel Office

Jonathan A. Sweemer
Venture Capital Officer
Treasurer's Office

N. Charles Thomas
Assistant to the Director of Admissions
Admissions Office

Moya L. Verzhbinsky
Staff Associate, Undergraduate Academic Support Office
Dean for Student Affairs

Sally D. Vlamis
Technical Writer
Administrative Systems
Development

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

John B. Wyatt
Supervisor,
Operations Center
Physical Plant

NEW APPOINTMENTS

Caroline Abeln
Senior Technical Consultant
Telecommunications
Systems

David B. Achenbach
Assistant Manager,
Labor Relations
Personnel Office

Maureen Ahern
Buyer
Purchasing and Stores

Rosalie M. Allen
Manager of Sponsor
Relations
Leaders for Manufacturing
Program

Marylene Altieri
Librarian
Libraries

Mary E. Avila
Route Supervisor,
Building Services
Physical Plant

Michael Barrow
Consultant
Computing Support
Services

Mary Barry
Assistant to the Bursar,
Student Services
Office of the Bursar

Louise L. Barteau
Coordinator,
Master's Program
Sloan School
of Management

Stephanie K. Bartling
Staff Assistant,
Undergraduate Academic
Support Office
Dean for Student Affairs

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PROVOST

The 1991-1992 academic year represents my first full year as Provost, and this report summarizes the highlights of my activities for this period. My own activities are covered here and detailed reports from those who report to me are included elsewhere in the Report to the President. I remain grateful for the strong efforts of those who have been working closely with me on a day-to-day basis, Mary Calderazzo, Christine Graves, Doreen Morris and Laurie Scheffler. These are the people who make the work of the Provost enjoyable, effective and efficient.

During 1991-1992 several major personnel changes have been made and there have been some changes in responsibilities for several members of Academic Council. Several new Institute-wide academic initiatives have been launched this year, and these will be summarized in the sections below.

Personnel and Organization Changes

As of the end of the academic year the Academic Council appointments have been completed. Professor William J. Mitchell from the Graduate School of Design of Harvard University accepted appointment as Dean of the School of Architecture and Planning, effective July 1, 1992. Dean Mitchell succeeds Dean John P. de Monchaux who announced his intention to conclude his term as Dean in the Spring of 1991.

Several other appointments and changes in the structure of Academic Council were made during 1991-1992. Professor Sheila Widnall was appointed Associate Provost, effective February 1, 1992, with responsibility for major faculty issues such as a review of the processes surrounding promotion and tenure, retirement, and academic responsibility. She also chairs a council on federal relations and has responsibility for programs related to internationalization. Professor J. David Litster was appointed Vice President and Dean for Research, effective February 1, 1992, with line responsibility for major laboratories and centers and the faculty and programs conducted in Whitaker College, including the Division of Health Sciences and Technology (a joint program with the Harvard Medical School).

Other Academic Council changes, effective February 1, 1992, have been made to enhance the role for the academic leaders of the educational enterprise, and the changes also flatten the organization. First, Professor Frank E. Perkins continues as Dean of the Graduate School, but reports directly to the Provost, rather than through an Associate Provost. Second, Professor Arthur C. Smith has taken on responsibilities related to undergraduate education and holds the position of Dean for Undergraduate Education and Student Affairs. He, too, now reports directly to the Provost. Professor Samuel J. Keyser has been appointed Associate Provost for Institute Life serving to develop programs to build collegiality among faculty, students, and the administration. He is also responsible for developing programs to assist new faculty in making the transition to M.I.T. Finally, the Provost now chairs the newly formed Education Committee, a sub-committee of Academic Council that will be concerned with resource allocation, new program development, and educational policy.

Margaret L. A. MacVicar Faculty Fellows Program

Our distinguished colleague, Dean Margaret L. A. MacVicar, passed away on September 30, 1991 after a more than year-long battle with cancer. Her enormous contributions to undergraduate education, including the establishment of the Undergraduate Research Opportunities Program, are well known at M.I.T. and around the nation. To honor Margaret's life and contributions the Faculty Fellows Program (approved last year by Academic Council and crafted with Margaret's active involvement) has been named the Margaret MacVicar Faculty Fellows Program, and in February the first six MacVicar Fellows were announced. The Program is intended to enhance and recognize contributions to undergraduate education by members of the faculty. Each Fellow holds the position for ten years and six to eight Fellows will be appointed each year, bringing the group to a steady state of 60 to 80 faculty. Each Fellow will receive a scholar allowance to

advance contributions to undergraduate education, and each Fellow will receive their academic year salary from a combination of endowment income and general funds. "Hardening" faculty salaries, particularly in science and engineering, is an important goal and recognizing our most outstanding undergraduate educators in this way is most appropriate. Endowment for the MacVicar Fellows Program is needed and the Exxon Foundation has pledged $1 million dollars for this purpose. We are also grateful to Cecil Green for his support of the Program.

The first six MacVicar Fellows are Professors Hal Abelson, Ed Crawley, Dan Kemp, Arthur Mattuck, John Southard, and Graham Walker. Nominations for appointment as a MacVicar Fellow are to be solicited from the M.I.T. community each Fall, and selections are to be announced at the beginning of the Spring term.

Colloquium on Teaching Within A Research University

As one of the events of the "Inaugural Year", a colloquium was held to discuss teaching at M.I.T. The event was well-advertised and drew Institute-wide participation. Indeed, the program in Kresge Auditorium was the most well-attended of any M.I.T. Colloquium; the follow-up events that evening also engaged many individuals in small group discussions. The colloquium had the effect of raising consciousness of the desire for synergy between education and research and the need to be mindful of the fact that the central mission of the university is to educate people. There were many subsequent discussions and actions taken in academic departments, including commitments to enhance workshops for teaching assistants and faculty, to videotape lecturers and provide a critique, to recognize excellent performance with new award programs, and to dedicate resources for innovation in educational programs. My own strong views on this matter influenced the decision to restructure Academic Council to focus more on educational programs.

Faculty Recruiting and Retention: Special Programs for Women and Members of Underrepresented Minority Groups

Two programs have been announced in 1991 to enhance the faculty by placing emphasis on recruiting women and members of underrepresented minority groups. For each program each academic unit has appointed a senior faculty member who will be a member of an Institute-wide group which will meet with the Provost from time to time to review progress, network, and share ideas. In each program there are financial resources intended to make it possible to recruit aggressively, even when no position nominally exists. Additionally, financial resources to support short term visits by distinguished women and minority group members are available in the Office of the Provost.

Council on Global Environment

In the Fall of 1991 the Council on Global Environment was formed, and I serve as its chairman. This group includes individuals having an active interest in education and research related to environment and has the purpose of serving as a forum for discussion of M.I.T. activities and opportunities for future contributions. The Council is to serve as the central point of contact with respect to the role M.I.T. will play in addressing education and research related to environmental problems. Education and research in this area involves a broad set of M.I.T. units, including Lincoln Laboratory, the M.I.T./Woods Hole Oceanographic Institution Joint Program, Whitaker College, and our five schools. An important point is that M.I.T. has a strong tradition of interdisciplinary collaboration and research. This remarkable tradition now must be expanded to include the social sciences, the Sloan School, and the humanities, in order to approach the leading questions related to environmental concerns. The Council on Global Environment is constituted to promote the cross-cutting initiatives that are needed to have major impact in environmental education and research. Programs such as the Program in Environmental Engineering Education and Research (PEEER), directed by Professor David Marks, and the Joint Program on the Science and Policy of Global Change, co-directed

by Professors Ron Prinn and Jake Jacoby, illustrate some of the efforts under way to work across traditional disciplinary, school, and departmental lines.

Dibner Institute-M.I.T. Partnership: Scholarly Activities Devoted to History of Science and Technology

In June of 1991, M.I.T. officially entered into an affiliation agreement with The Dibner Institute, Inc., The Burndy Library, and The Dibner Fund. The common objective of the parties of this affiliation is to create the world's leading academic center for the study of the history of science and technology. We have been most fortunate to enjoy the generous support of David and Frances Dibner who have committed substantial resources to continue the lifelong interests of Bern Dibner in the history of science and technology. The Burndy Library, which includes a collection of books, manuscripts, and scientific equipment, will be housed at the Dibner Institute on the M.I.T. campus. This rich scholarly resource, alone, represents an attraction to scholars around the world. M.I.T. and the Dibner Institute have attracted Dr. Jed Z. Buchwald to take on a major leadership role, serving as the founding Director of the Dibner Institute and the first Bern Dibner Professor. The Dibner Institute-M.I.T. partnership is one which includes several of the Boston-area universities in the form of a Consortium. Consortium Members include Harvard University, Boston University, Brandeis University, and M.I.T., and this group comprises a strong intellectual community around which to build a scholarly program of international importance. M.I.T. welcomes this new partnership to build an important and exciting area of scholarship.

Renewal of the Athena Computing Environment

Advances in computation capability continue as new hardware and software become available. Renewal of the Athena computing environment is essential in order to maintain a leadership and growing role in the use of technology in campus communications, education, and research. During 1991-1992 we have embarked on a program to renew the Athena hardware with state of the art workstations. The first new machines from DEC were installed before the end of the fiscal year and plans are to continue the renewal program for the next three years. The Athena computing environment remains vital to about 100 subjects each term, and the use of Athena among the M.I.T. community continues to grow. This asset provides extraordinary resources for our students, faculty, and staff.

Council on Primary and Secondary Education

A Council on Primary and Secondary Education has been formed and Professor Ronald M. Latanision has been appointed to be its chairman. The purpose is to develop M.I.T. programs to address problems in primary and secondary education in the United States. The formation of the Council is an outcome from an ad hoc committee study to assess whether there are effective and appropriate roles for M.I.T. in dealing with issues facing the pre-college education system. The Council consists of faculty and staff with a determination to develop programs which will have national impact, either directly or as models for others. Programs underway on the M.I.T. campus include a summer institute for high school teachers, a week-long program for high school science and mathematics teachers to become acquainted with cutting edge science and engineering activities, a high school teacher sabbatical program, and numerous outreach efforts. A Minor in Education for M.I.T. undergraduates has been proposed and is likely to be available for students in the Fall of 1992.

Budget Issues

Hardening Faculty Salaries in the Schools of Engineering and Science. Efforts continue to "harden" faculty salaries in the Schools of Engineering and Science. In the School of Science Assistant

Professors have been hired with full academic salary support budgeted in the departments involved, and during 1991-1992 faculty recruiting has been conducted in the School of Engineering with the understanding that newly appointed Assistant Professors will also be budgeted at full academic year salary support. Senior faculty appointed from outside M.I.T. and new appointments to endowed professorships in Engineering and Science are also being made with full academic year salary support. These efforts are already having a positive effect on faculty morale and should lessen the pressure on junior faculty. As indicated above, the MacVicar Fellows Program is another opportunity to harden salaries in Engineering and Science. Replacement of highly paid retirees with assistant professors, modest budget enhancements, and increased number of endowed professorships will bring about continued progress on hardening faculty salaries.

Faculty Travel and Moving Expenses. With growth in funds in departments it would appear plausible that local financial resources should be adequate to cover the cost of the faculty travel program and the moving expenses incurred by newly appointed faculty. Thus, the central budgeting of these items has been terminated, as a consequence of considerations of budget priorities during the Five-Year Planning Process. Obviously, local difficulties may arise and these can be addressed by the Deans or by my office. This budget cut assisted in making it possible to restrain the tuition increase.

Non-Recurring Capital Equipment. For about ten years the Institute budget has included $700,000 annually for the acquisition of non-recurring capital equipment. These resources were typically used by academic departments for small pieces of equipment in laboratory subjects. While these resources are valuable, it would appear that the funds are not regularly spent. Further, as with faculty moving expenses and travel, it would appear that departments can assume a larger fraction of such expenses, since their fund accounts (in aggregate) have grown more rapidly than central resources. Thus, the budgeting of non-recurring capital equipment with central funds has been terminated based on consideration of budget priorities during the Five Year Planning Process. This cut contributed to our holding tuition to a modest increase, and non-recurring capital equipment needs can be met with funds available at the departmental, dean, or provost level. Major needs should be met, at least partially, with resources secured from external sources such as federal agencies, foundations, and individuals.

Unrestricted Gifts. The operating budget has become too reliant on unrestricted gifts, with a dedication of about $9 million dollars in unrestricted gifts to current operating needs. Independent of whether we are able to sustain contributions at this level, it would be more prudent to build the endowment with these resources. Building the endowment with greater capital contributions in the years ahead would contribute to our maintaining an approximately 5% growth in revenue from endowed funds. This will be critical to increasing faculty salaries, since we have been so successful in securing so many endowed professorships. A shortfall in budgeted unrestricted gift revenue is a one-for-one contribution to a budget deficit. Steps need to be taken to reduce our dependence on unrestricted gifts for current operating needs.

Indirect Costs of Research and Graduate Student Tuition. There is the real possibility of changes ahead in the partnership with the federal government in connection with sponsored research. Accordingly, I appointed an ad hoc committee of faculty and administrators, chaired by Professor Robert Weinberg, to address the issues from the faculty perspective. The group certainly became better aware of how indirect costs are supported, and there were several useful recommendations from the group. The concept of a single indirect cost rate for all of the campus was endorsed, but only after considerable debate. However, it was recommended that there be "incentives" to use space efficiently. Further, it was recommended that the Institute embark on a continuous improvement program aimed at improving services supported by indirect costs and also cutting expenses. With respect to graduate student tuition, the main issue involves whether the Institute will be allowed to continue its practice of including the tuition of graduate research assistants and teaching assistants in the fringe benefit pool. Direct charging of tuition is expected to adversely affect Ph.D. production in science and engineering owing to the fact that research assistants become more expensive. If we are to maintain the current size of the graduate student body, more Institute subsidy to

support graduate students is likely to be needed in order to remain competitive with other institutions. Some thoughtful suggestions emerged with respect to revenue enhancement, but many of the areas of inquiry could not be dealt with in the short time available for the group to do its work. Focused study of several issues is required in the near future.

The seriousness of the changes in the support of indirect costs issue can be measured by the fact that the Institute will lose between $2 and 4 million in FY92, as a consequence of changes in government practice in the recent past. This has an immediate and continuing negative impact on the bottom line of the budget of M.I.T.

Campaign for the future

Balancing the negative tone of the foregoing budget issues is the achievement of the goal of our capital campaign. On June 26, 1992 I had the good fortune to participate in an event to celebrate the achievement of the $700 million goal of the *Campaign for the future*. This success can be attributed to the extraordinary efforts of a very large group of people starting at the top with our Chairman, Dr. Paul E. Gray. Vice President Glenn P. Strehle is to be congratulated for mounting such a successful effort, and he and the other members of Resource Development have worked tirelessly to strengthen the financial base of the Institute. Our Association of Alumni and Alumnae led by Bill Hecht has also played an extraordinary role in achieving success. Of course, the individuals, corporations, and foundations who have contributed to the Campaign deserve our collective thanks for the confidence and trust they have placed in us.

In the past year alone, the benefits of the *Campaign* have included numerous endowed professorships, flexibility to support new academic initiatives ranging from environment to offering of subjects in Chinese language and culture, and resources to sustain the highly successful Leaders for Manufacturing Program of the School of Engineering and the Sloan School of Management. Resources from the *Campaign* have been used to maintain and selectively enhance the academic programs offered by the Institute.

With the resources secured during the past five years and the enormous untapped potential, I am confident that we can realize many of our educational and research goals in the future. With the careful and prudent management of the past administrations and the successful campaign, we have the flexibility to adjust our ongoing operations in a responsible fashion to adjust to the economic realities and concomitant restraints of the 1990's.

MARK S. WRIGHTON, Provost

MISSION STATEMENT

The Center for Educational Computing Initiatives(CECI) was created in July, 1991 to advance the state-of-the-art and state-of-the-practice in the use of computation and communication technologies in education. The creation of the Center was one of the recommendations of the Committee on Academic Computing in the 90's chaired by Dean Margaret Macvicar. The creation of CECI, reporting directly to the Provost, and the migration of the operating responsibility for Project Athena to MIT Information Systems were the two major strategic decisions made by the Institute as Project Athena neared its June, 1991 ending date.
In brief, the center's is as follows:

> CECI undertakes research in the application of computer and communications technologies directed towards the goal of improving the effectiveness and productivity of learning and education.

Implicit in this mission statement is the hypothesis that new technologies can improve the quality of education in many areas and that a sustained research focus on such uses of technology will, over time, yield such improvements. An interdepartmental, MIT-wide center such as CECI is essential because such research does not fit well within traditional departmental organizational structures.

MAJOR INITIATIVES

Projects in CECI focus on the three following areas:

•the development of technologies that enable educational applications, including authoring systems, toolkits or libraries of computer code that make the creation of effective computer applications easier and less expensive;

•the authoring of new educational applications of computation and computer technologies;

•studies of how various uses of computer technology affect education, particularly the extent to which innovations in computer applications improve the quality of education.

Some of the major initiatives already begun or in planning are described below.

AthenaMuse: A Multimedia Authoring Environment

CECI is developing a software authoring system called AthenaMuse with the following goals:

•To build a suite of highly interactive, visual, and user friendly multimedia editors that support all phases of the creation of multimedia applications. The goal is to provide a set of tools for multimedia applications that can be used by subject experts who are not programmers.

•To develop an improved multimedia runtime environment for the presentation of multimedia documents and interactive applications in a distributed network environment as well as in stand-alone modes.

•To provide independent object libraries that will facilitate the introduction of new multimedia modules and will allow the combination of multimedia components with other software technologies such as three-dimensional rendering, an object oriented database and natural language analysis.

•To define a platform-independent language to describe multimedia applications. The software will provide a low level structured application interchange format that will allow a multimedia application authored on one computer system to run on another that may have very different media peripherals and screen resolution.

•To create content-rich applications that span a wide range of educational areas, including in-class instruction, tutorials, museum collections and library applications.

This initiative continues MIT's leadership in multimedia authoring environments for educational applications and the development of applications themselves. The software development is being undertaken by an industrially-sponsored research and development consortium. This group, called the AthenaMuse Software Consortium, includes both MIT sponsored research staff and full-time industrial visitors. It builds directly on the extensive work on multimedia computing done in Project Athena's Visual Computing Group.

The AthenaMuse Software Consortium currently has nine sponsors representing corporations, government organizations and universities in Europe, Japan and the US. The Consortium's total funding $800,000 per year, of which approximately $150,000 consists of grants of hardware or software.

Environmental Education

Environmental education an area in which computer and communication technologies have enormous potential. This is in part because environmental studies are typically multidisciplinary in nature, making them a fertile area for tools that allow sharing of different expertise. In addition, learning about the environment can be aided by giving students access to visual images of remote locations (as in studies of the Antarctic ozone hole), providing them with a wide range of data (as in studies of ocean currents or global warming), or providing them with sophisticated simulation tools that allow them to trace the complex economic and social effects of environmental decisions (as in the regulation of CFC's or shifts in automotive pollution control standards). All of these aids can be provided by the technologies at the center of CECI's intellectual interests.

CECI is currently working with the Rene Dubos Center for Human Environments, an environmental education group in New York City, on a series of multimedia computer applications targeted to middle school students. The planning of this series and the first application have been funded by United Technologies. Support for the rest of the series is now being sought.
CECI is one of the participants in MIT's proposal to IBM's recently-announced Environmental Research Program. Our role in this project will include the development of an MIT-wide environmental information server, working with faculty to develop educational software and the design and operation of a computer-based seminar room for environmental studies.

CECI is also a participant in a proposal to the European Economic Commission led by the French equivalent of the Chamber of Commerce to develop a computer application on pollution control for practicing professionals. Funding for this work is still being sought by our European partners.

CECI is working with the American University of Beirut under funding from the Hariri Foundation to develop multimedia software that explores the water resources of Lebanon. This project is part of a the Technology and Development Program.

Networking for K-12 Education

CECI has proposed to develop computer systems that encourage collaboration between K-12 students and teachers, and scientists and engineers in industry and in universities, with the aid of computer-based networks. This program, called Access, will serve as a model for how practicing scientists and engineers can participate meaningfully in K-12 education.

The Access Project has the following goals:

- Access will make MIT the coordinator for electronic communication between K-12 students and the community of faculty, research staff, alumni, scientists and engineers in industry and MIT students who want to participate in science education.
- Access will foster individual participation by people all within and outside of the MIT community by supplying information on how to get involved and providing technical and financial support. Access will also sponsor more organized and larger-scale projects as frameworks for participants to collaborate with K-12 students and teachers via the network.
- Access will provide K-12 teachers and students with to advice and information resources that are otherwise difficult for them to obtain.
- Access will provide a means for K-12 teachers, administrators and students who participate in on-campus programs at MIT and other institutions to maintain ongoing contact with each other and with the faculty.
- Access will facilitate communications within the science education community and provide intellectual support for K-12 teachers who would otherwise be isolated.
- The Access program will provide a scalable model for how other research universities can get involved in science education.

The central challenge in Access to is involve a large community in activities that directly benefit K-12 education. Through Access, MIT will invite universities, industries, and other research organizations to join a coalition that promotes involvement by the research community in K-12 education. Each member university or company would name an Access coordinator to help organize network-based educational activities. All coalition members would engage in Access activities on the same basis as members of the MIT community, and MIT would provide formal recognition for participants by, for example, designating special instructor status for significant work and hosting on-campus activities for Access instructors.

Specific activities that will be undertaken under the Access project include: making important public databases such as satellite images available over the Internet; conducting design competitions for secondary school students; creating and managing a pool of scientists and engineers who can serve as electronic advisors to students and teachers; and, offering "electronic classes" on subjects that go well beyond the regular secondary school science curriculum.

Foreign Language Projects

Languages will be taught in the future less from a book-centered approach and more from an immersion in authentic speech. The ability of multimedia computer technology to provide a simulated environment in which the sounds and images presented to the student reflect the native speech and culture of a foreign country makes it a powerful tool for language instruction, perhaps second only to actually being in the other country.

MIT is positioned to be an international leader in this effort. The Athena Language Learning Project at MIT created award-winning multimedia computer applications to teach French and Spanish. Dr. Janet Murray (Senior Research Scientist), Gilberte Furstenberg (Senior Lecturer in French), Douglas Morgenstern (Senior Lecturer in Spanish), and Professor Suzanne Flynn (who specializes in Linguistics and English as a Second Language) all from the Foreign Languages and Literature Section, and Evelyn Schlusselberg and Ben advisability currently CECI researchers) developed these applications.
Since CECI started, additional projects in Spanish (involving CECI staff and Evelyn Lillienfeld, a lecturer in foreign languages, and Japanese(with Dr. Janet Murray and Prof Shigeru Miyagawa) have begun. This work will continue as a collaborative effort between the Foreign Languages and Literature Section and CECI.

The Shakespeare Interactive Archive Project

The Shakespeare Interactive Archive Project, directed by Prof. Peter Donaldson and Dr. Janet Murray, is creating a prototype software environment for studying text and film of Shakespearean plays as an aid to learning and to scholarly research. This project addresses key questions of how to index and annotate electronic and performance texts so that they are readily accessible to multiple, concurrent users. These efforts coincide with a shift in emphasis in Shakespeare studies toward the serious study of performance at the micro, or highly detailed, level.

The Shakespeare Archive is also expected to contribute in the long-range to work in Film/Media at MIT, in particular to the effort to access film materials in relation to text and commentary and to create a new kind of classroom in which video and text sources are integrated and made readily available for analysis.

Other Literary Projects

There is also interest in pursuing, in conjunction with the Modern Language Association and the library initiative, formats for accessing large text databases over the network. One such database, a public domain Shakespeare corpus, compiled at the University of Toronto, has been offered to us as a testbed.

Another potentially fruitful area in the humanities is the creation of an on-line textbook for use in teaching in an electronic classroom situation. For example, one might take an existing, conventional book of short stories and use it to create an electronic version which would be indexed for image patterns, opening lines, etc. The electronic version could be used by the instructor in-class to compare ideas in writing across different authors or to trace the evolution of major themes used by one author in different stories.

Dr. Janet Murray has been exploring these possibilities. She is also initiating a course on non-linear and interactive fiction. This will be taught in the spring of 1992 for the first time. It will involve the students in creating new narrative structures on the computer.

Museums, Archives and Libraries

Museums, archives and libraries share a common need to provide information to broad constituency. CECI has been working with several such organizations to explore the potential of computer and communication technologies to aid in this mission. In several cases, CECI staff have created prototypes of computer applications that allow users to browse the rich information resources of such organizations. Specific projects include:

- a project with the MIT Museum to create an multimedia collection describing the life and work of Doc Edgerton. This project is the first in a proposed series on famous MIT researchers.
- a prototype of an application (and a proposal for continuing work) on new techniques for computer-assisted reading for the new Bibliotheque de France.
- a prototype with the Smithsonian Museums showing a portion of their Native American collection.
- a project being undertaken with the Rotch Library to deliver portions of their collection of still images over the campus network.
- collaboration with the National Gallery and GTE Imagespan on digital image transmission and storage.

•a proposal with the Harvard University Collection of Historical Scientific Instruments for computer applications that describe the history of particular subcollections, including time-keeping instruments, telephones and microscopes. A prototype application showing their sundial collection has already been developed.

•a prototype for human interface research for the Musee D'Orsay in Paris.

Journal of Science Education and Technology

CECI is the home for a new journal in the use of information technology in science education. The publication is entitled the *Journal of Science Education and Technology*. It covers all levels of education, including K-12. Dr. Karen Cohen, a Senior Research Associate, is the editor of the journal, and Prof. Steven Lerman, director of CECI, is on the editorial board. Plenum Press is the publisher.

MIT faculty and research staff are encouraged to use the journal as the scholarly publication of choice for educational computing. This connection will provide peer review for young faculty who are interested in this area but are concerned about how such work will be recognized in the tenure and promotion process.

RELATIONSHIPS WITH OTHER MIT ORGANIZATIONS

To be successful, CECI must establish working relationships with many other organizations both at MIT and elsewhere. These relationships are mutually beneficial, with both CECI and the other organizations gaining from the cooperation. One pattern of cooperation already emerging is where MIT academic departments or outside organization provide their substantive knowledge of some field and CECI provides the computer application design/implementation expertise to build an educational system.

This section describes some of the most significant of the relationships already formed or envisioned as important to achievement of CECI's goals in the next five years.

Academic Computing Council

CECI is closely tied to the MIT Academic Computing Council. The Director of CECI chairs this council, and the group acts as an informal steering committee for the Center. Major initiatives for CECI are discussed within the Council, and members of the Council are often active in these efforts. This close working relationship will continue, with Council members providing the core of the affiliated faculty of the Center.

Council on Primary and Secondary Education

One of the major areas identified by the Council on Primary and Secondary Education chaired by Prof. Latanision was the application of new technologies in education. Given CECI's mission, it makes sense for us the Center to focus some of its energies on realizing this goal.

As a concrete step, Prof. Hal Abelson, the co-principal investigator of the Access Project described above, presented that initiative to the Council on Primary and Secondary Education. The Council endorsed the project as one of the major initiatives MIT should undertake. This joint approach serves as an excellent model for how CECI and the Council on Primary and Secondary Education will work together in the future.

The MIT Libraries

There is substantial opportunity for collaboration between CECI and the MIT Libraries. As discussed above, the libraries are one of the major participants in the Distributed Library Initiative. CECI may play a major role in some of the research initiatives under the larger umbrella of DLI, particularly in the area of image delivery. As part of Project Athena, several CECI staff worked on the pilot electronic image delivery system that provided network access to a collection of 3,000 slides in the Rotch Visual Collection. We are planning to update that system to provide broader access and digital images. (The earlier system used analog transmission of images via the MIT CATV system.)

Information Systems

CECI retains a close working relationship with the part of MIT Information Systems that now operates the Athena Computing Environment. This relationship includes shared facilities, seminars, and joint participation in several initiatives.
Much of CECI's current computing capability runs the Athena software system and is maintained under contract by Information Systems. While CECI operates computers for its research needs that are not part of the Athena system, some portion of our computer system will be kept Athena-compatible.

Current research in CECI is developing enhancements to the Athena computing system in areas such as multimedia and scientific visualization. To the extent that CECI demonstrates the importance of new technologies in university education, these capabilities will over time be incorporated in some form in the Athena system. Clearly, such technology transfer will be very case-specific, depending on the costs of the technology and the funding available for the Athena system.
Because of their physical proximity in Building E40, CECI and Information Systems share some facilities. For example, the Visitors' Center, equipped with a range of computer hardware and projection capabilities serves the needs of both organizations.

CECI Staff and Space

CECI currently has eight full-time MIT employees (including the Director of the Center), three full-time visiting research scientists and approximately six graduate and undergraduate research assistants. Four of the staff currently in CECI were part of Project Athena.

The center currently occupies approximately 2400 square feet of usable space on the third floor of Building E40(The Muckley Building). This space include nine offices (totaling) about 1300 square feet), cubicle space for student assistants and administrative support, and three carrels intended for use by UROPS. The center also has a small video editing studio in the basement of E40. This facility is used for making master videotapes and working videodiscs used in the development of multimedia computer applications.

All of the work areas are equipped with network connection to the campus network and cable TV access. This infrastructure is essential for the research done at the Center, particularly our work with multimedia computing.

Many of the initiatives in CECI will be done in the space of the home departments of the participating faculty. In the long run, CECI should become a hybrid between a "virtual center" and a more conventional research laboratory. Some of the research of the Center will be done by full-time staff housed centrally in CECI space, while other projects will be done by faculty, students and staff belonging to other groups on campus. This approach will allow CECI's activities to expand without requiring a commensurate growth in the Center's space.

GOALS FOR NEXT FIVE YEARS

CECI has a number of major goals for the next five years. In particular, CECI has adopted the following goal

•CECI should continue to be part of several major, state-of-the-art initiatives in educational computing. These initiatives should draw on the Institute's traditional strengths in computer and communications technology and our recognized leadership as an educational institution.

•CECI must become the focus of a community of faculty, staff and students who share a common interest in educational computing. This is essential because most of our academic departments have only one or two faculty with interests in this area. Without a more Institute-wide community, these individuals lack both the peer support and financial resources for sustained, effective research.

•CECI should provide a testbed for new ideas that, if successful, can influence the campus computing environment built under Project Athena. In effect, part of CECI's role is to explore the possible strategic directions the campus computing environment should take and to identify those directions that, at least in small scale experiments, seem the most promising.

•CECI should increase the group of undergraduate and graduate students who, while working on degrees in various other academic departments, want to focus their research on educational computing.

•CECI should assist faculty in finding the external funding needed for educational computing initiatives. This assistance will take the form of direct fund-raising, help in proposal preparation, provision of seed grants for promising new ideas and the organization of consortia.

•When appropriate, CECI should provide technical assistance to educational computing projects. For example, CECI staff should include individuals with specialized skills that can be used as part of a number of different projects, no one of which could support someone with that expertise full-time.

•CECI's initiatives should have a direct effect on the MIT curriculum, ideally affecting some of the fundamental, core undergraduate subjects.

STEVEN R. LERMAN

Council on Primary and Secondary Education

Virtually every American college, university, cultural institution, and business or industrial organization with a conscience is involved in some way with K-12 education. This is true of MIT as well in terms of the many independent outreach activities that have emerged over the past few years from departments, centers, and groups of faculty, staff, or students. Despite all the effort and money directed at the K-12 system since *The Nation at Risk* first sounded the alarm in 1983 concerning American education, there is little to show for it. Systemic and cost effective change is likely to occur only when concerned institutions, businesses, and government agencies become partners in a broader agenda. At present, fragmentation and proprietariness are symptomatic of educational reform in America.

The Council on Primary and Secondary Education, or CPSE, a body established at MIT to implement the recommendations of the Committee on K-12 Education (which are published in the report *Education: To Move A Nation*), has taken a systems approach in engaging K-12 education. During AY 91-92, the Council has developed an institutional agenda that is considered meaningful in terms of the nation's needs and tractable in terms of the intellectual and fiscal resources that are required of the MIT community in moving forward.

MEMBERS AND STAFF OF THE COUNCIL ON PRIMARY AND SECONDARY EDUCATION
During AY91-92 the following faculty, students, and staff have served as members of the Council:
Hal Abelson, RSI/EECS; Jeanne S. Bamberger, Music & Theater Arts; Michael C. Behnke (ex officio), Director of Admissions; William Bertozzi , Physics;Roger Brooks, Physics; Larry Bucciarelli, ECSEL; Susan Carey, Brain and Cognitive Science; Naomi F. Chase (ex officio), News Office; Alan Dyson, T.I.D.E. Senior Education Specialist; Maurice Fox, Biology; Will Glass, ESP, MIT Undergraduate Representative; Richard M. Held, Brain & Cognitive Science; Tom Hsu, MIT Graduate Representative; Gregory A. Jackson, Director of Academic Computing; Ron Latanision, Chairman, DMSE; Alan J. Lazarus, Physics; Lawrence M. Lidsky, Nuclear Engineering; Robert McKersie, Sloan School of Management; Joel Moses, Dean of School of Engineering; J.J. Pitts, Office of Minority Education; Mitch Resnick, Media Lab; Judah Schwartz, Engineering; Arthur Steinberg, Integrated Studies Program; Leon Trilling, Aero/Astro Department; and John S. Wilson (ex officio), Resource Development.

The CPSE staff includes Constance Beal, Administrative Assistant, Jonathan Bartels, Coordinator of K-12 Activities and Administrative Officer, and Linda Breisch, Communications Manager.

STRATEGY
The low level of technical literacy among the general public and declining interest and achievement in science and engineering education among young Americans will adversely affect America's workplace of the future and the effectiveness of its citizenry. Our strategic objective is to develop a process to ensure the technical literacy of *all* Americans and to encourage youngsters who are inclined toward technical education to pursue these interests.

TACTICS
In directing human and fiscal resources to secure our objectives, several characteristics stand out.

- The educational enterprise is a large-scale systems phenomenon and is considered accordingly in our agenda. Reform and change are required not only in K-12 classrooms, but in living rooms, boardrooms, and legislative hearing rooms. Our entire social, economic and political infrastructure has a stake in the education of young Americans. It is the *system* which is failing and the system is more than the schools.

- Given this systems approach and the recognition that technology is integral to the social and economic fabric of our society and to life on earth, our institutional initiative involves not just the science and engineering schools but, rather, includes all of the schools at MIT and is expected to draw broadly from the MIT community — faculty, staff, students and alumni.

- MIT's approach to educational reform is that of an institute of technology, not of an education school. Our emphasis is likely to be different with regard to K-12 education.

- Partnerships or alliances are central to our K-12 efforts at MIT. It seems clear, given the scale of the problem at hand — the reform of the American K-12 educational system — that independent initiatives are likely to continue to produce fragmented results. The total will become greater than the sum of the parts only if people and institutions are truly willing to collaborate. We shall develop alliances, therefore, with organizations having values comparable to those reflected in *Education: To Move A Nation.*

AN AGENDA FOR CHANGE

The Council has looked carefully at the suggestions for reform measures that began to appear with *The Nation at Risk* and recently included *America 2000*. The Council concluded that no reform measure will be as successful as hoped without a corresponding change in the public attitude toward the value of education and, particularly, achievement in education. The agenda presented below is sensitive to this need to bring the American public along with educational reform. We believe that recognition of this need has been absent from the discussion in the past.

Public Commitment to Academic Excellence

Americans respond when they perceive a national emergency, an urgent threat: Sputnik, the Cuban Missile Crisis, the Gulf War are examples. The public responds to immediate personal threats of other kinds: smoking tobacco, declining fitness, cholesterol and dietary inadequacies. However, there is no sense of urgency in the general population concerning education or, for that matter, the declining competitiveness of American industry. In effect, the global challenge to the US applies as well in commerce and in education. There is a troubling symmetry in the decline of our industrial base and of our educational system. It appears that as a nation, we undervalue both!

The Council believes that this attitudinal change or cultural change must become central to our initiative: we have, therefore, proposed a media or communications campaign designed to change attitudes about the value of education and, particularly, achievement in education. The key is finding the right hook to engage, not just expose, the public to the issues. National emergencies work; health works. They are of immediate concern. But to engage the public with regard to education or industrial productivity (competitiveness) is more difficult. ***We think that the hook is the decline in our standard of living today — and in the future for our kids.*** We propose, therefore, to work with network and public television in constructing a public information campaign designed to change the educational culture of America — to change public attitudes: the linkage between education, productivity, and standard of living can be made clear. We have begun to work with the CBS-affiliate in Boston, WHDH, in an 18-month campaign, *Imagine That*, the first, hour-long segment of which was broadcast in primetime on 31 May 1992.

It should be emphasized that this media campaign is central as well to the Massachusetts Department of Education proposal to the NSF Statewide Systemic Initiatives Program, *Partnerships Advancing Learning of Mathematics and Science* (PALMS), of which the MIT Council Chairman is co-principal investigator along with Dr. Susan Zelman, Associate Commissioner of Education, and Professor Michael Silevitch of Northeastern University. The program carries a $10 million budget over a five-year period. The Council staff has also been an effective participant in the evolution of the educational reform legislation which is working its way through the State House in Boston.

Teacher Enhancement and Curriculum Development: Summer Teacher Institutes

We are not teaching math and science well. Our schools are not preparing their graduates to succeed in college-level work in science and technology, nor are we giving our future work force the technical competence it needs to compete effectively in world markets. Our purpose is to work with K-12 teachers of math and science in developing new, more effective methods of presenting their subjects by using technological themes as their vehicle. We believe that implementation of an integrated, contextual approach to the teaching of math and science has the potential to engage a larger fraction of the youngsters passing through our K-12 system. If, as is our goal, the target is to produce a technically literate work force and citizenry, we must engage more than the 20% of the total school population now likely to take chemistry in high school (even fewer take physics). Clearly, broad science literacy will not be a product of a system in which only a small fraction take these courses. A clear illustration of how science (and technology) is integrated in human terms into the social, economic, and political fabric of our society will, we think, attract more youngsters into our K-12 science and math classes and, ultimately, reverse the nation's technical illiteracy.

During the summer of 1992 we will initiate our Summer Teacher Institute by recruiting 65-100 K-12 teachers and administrators from public schools in and around Cambridge and Boston who will spend three weeks at MIT with industrial professionals and members of the MIT community (faculty, staff, and students) in a pilot Summer Teacher Institute. Though our workshops will emphasize science and math in a technological context, we will not limit participation to science and math teachers, but will seek the different perspectives of other fields as we formulate an integrated approach to learning.

During this first summer, curricular materials will be developed around the theme: **How Does a City Work.** Our focus will be on a water distribution system and a metropolitan public transportation system. Teachers, with representation drawn from throughout the K-12 spectrum including vocational education, will work collaboratively to develop integrated curricular materials with technology serving as a focus for language arts, social studies, math, and other subjects. Support during this start up period has been provided by the Pew Charitable Trusts and by an anonymous donor.

Given that our values and those of the American Association for the Advancement of Science as represented in *Project 2061* are very much alike, we expect in 1992 to develop a working relationship with AAAS. Our hope is that our example will encourage other such alliances, thus stimulating a less fragmented national agenda.

Technological Advances in Education: Project ACCESS
While technology is not a "silver bullet" that can, by itself, reverse the declining quality of the K-12 educational experience, it can play a useful role. There is little doubt that as this decade moves on, electronics will become increasingly available in a curricular sense as well as in ways that will allow contact between youngsters and their teachers, on the one hand, and university and industrial professional on the other. We propose to establish a national forum for personal interaction between precollege students and teachers, and scientists and engineers in industry and academia, with the aid of computer communications networks. This program, which we are calling ACCESS, will serve as a practical model for how professional scientists and engineers can make effective personal contributions to precollege science education on a nationwide scale.

ACCESS will begin as a cooperative project between the MIT and Howard University, although we plan to expand it to other universities and to organize formal participation by industrial partners. In initiating ACCESS, MIT brings expertise in computing and network technology, leadership in science and engineering education, close ties to the academic and industrial scientific community, and experience in establishing partnerships with local school districts. Howard brings excellence in precollege education, and experience with inner-city populations that have been difficult to reach in science education. Both MIT and Howard will support ACCESS as a prominent institutional activity.

During this initial four-year project, we will intentionally explore a diversity of educational settings and activities, and a range of computer hardware options and interconnect strategies. We will also strive to collaborate with existing groups active in precollege educational networking. Our objective is both to implement a widely accessible resource for science education, and also to obtain experience that will guide educators and policy makers in making increased use of educational networking over the coming decade.

We will start ACCESS on a very small scale, with three or four schools at which we will provide extensive monitoring and support, and which we will use as guidance for controlled growth of the project. Within the scope of the present four-year proposal we will expand ACCESS to a size that is sufficiently large to demonstrate that our approach is both feasible and scalable. By the end of the four years, we expect that ACCESS participants will include about ten thousand teachers and their students and a few hundred scientists and engineers from industry and academia, including alumni of both institutions.

Supporting K-12 Teachers at MIT
By linking MIT's established traditions in higher education in math, science, and engineering; experienced teachers' potential for developing innovative approaches to teaching appropriate for children in a wide range of school settings, grade levels, and varied career goals; and thoughtful preparation of teachers with strong backgrounds in math and science, we foresee MIT making a contribution to the betterment of education generally, and science and math education in particular. The two joint programs which are envisioned can serve as a model for other institutions to adapt to the diverse settings and communities that characterize our nation's schools.

The Teacher Fellows Plan
MIT will undertake a long-term, supportive relationship with a group of teachers chosen yearly as MIT Fellows, perhaps carrying the name of one of MIT's most respected educational figures, Jerrold Zacharias. Fellows will begin with a sabbatical year at MIT. That year should be one of renewal and broadening for the teachers through a close collaboration with one or more MIT faculty/staff in a mutual exploration of ideas for making significant improvements in education.

Fellows will be at MIT for an academic year. We expect the Teacher Fellows Program to begin in the fall of 1992 with 5-8 participants recruited from the greater Boston area. For this first year, teachers will be recruited from middle and high school (future years may include elementary school teachers, as well). We would like to include more than one teacher form the same school district, preferably teachers from different grade levels so as to encourage dynamic interaction across usual institutional boundaries. Preference will be given to teachers from inner-city schools. They will be experienced teachers capable of contributing to significant change when they return to their school districts. It will be essential for MIT to work with superintendents, staff support people, and principals from Fellows' school districts before, during, and after the sabbatical year to insure a commitment from them to support a leadership role for Fellows in carrying out and disseminating their ideas when they return to their school districts. Fellows must also be prepared to play a mentoring role in working with our undergraduate teacher trainees while at MIT and later by helping to provide sites for student internships.

MIT Undergraduate Teacher Development Plan: The Minor in Education
The Undergraduate Teacher Development Program is closely linked with the Fellows program, participants in each program working together with and complementing the activities of the other. While the practical purpose of the Teacher Development Program is to develop means through which MIT undergraduates can gain teacher certification for middle and high school, its larger purpose is to design a program that will "speak to" the talents, skills, expertise, and ways of approaching and solving problems that give our students the potential to make important contributions to educational

change. In developing a program that seriously addresses the integration of subject content and innovative approaches to teaching, we also have the opportunity to create a model for other similar institutions that may wish to develop teacher training programs for their students. Since it seems likely that such programs will be on the rise, we are in a position to make a significant contribution.

We have designed an Education Minor which will begin in an experimental phase in September 1992. Students interested in teaching will complete an education minor in conjunction with a disciplinary major. The minor program will allow Massachusetts Teacher Certification in grade 6 through 12. Students who wish to teach at the K-6 level will need special courses already in place at Harvard and at Wellesley to meet certification requirements, and all students will need to understand general educational issues and goals — curricula, social and educational psychology, technology, support systems, administration, etc. With this relationship in place, combined with the critical mentorship of the Fellows, we can then offer students a full program that will meet the requirements for the Education Minor and for certification. The MIT Class of 1952 Educational Initiatives Fund provides the resources for the development of the minor program.

Support of Ongoing K-12 Programs

Our most publicly visible efforts to engage in K-12 education at the present are the many outreach activities that have been initiated during the past few years at MIT by departments, centers, and other entities. Some of these programs serve as the seeds for our institutional initiatives. Examples of these programs include the following:

- *The Science and Engineering Program for Middle and High School Teachers*, which led to the formation of an association of *New England Science Teachers* (NEST) working to promote science literacy.
- The *Chemistry Outreach Program*, which has placed MIT students in local schools to demonstrate the richness of chemistry to students and teachers.
- The Epistemology and Learning Group's LEGO/Logo based *Headlight Model School*, in association with the Hennigan Elementary School in Boston.
- The graduate student-managed Cambridge *Physics Outlet* which offers a week-long course *Introduction to Physics and Engineering*, an experience based, hands-on learning project.
- The *Educational Studies Program*, a student run organization that has since 1957 provided enrichment courses for thousands of local junior and senior high school students.

Many of these efforts operate on a volunteer basis. Most are underfunded. We wish to encourage the wide variety of independent efforts in K-12 education on the part of the MIT community. It is unlikely, however, that these programs can continue to function on a volunteer basis. While many proposals are now under consideration by various potential sponsors, we envision the development of a fund that could be made generally available for outreach programs. In effect, we now need to generate the fiscal base to sustain these programs into the future.

OTHER ACTIVITIES

In collaboration with Joe Perkell of the MIT Class of 1962, the Council chairman organized a Forum on Policy Issues in K-12 Education. The forum was keynoted by former US Senator Paul Tsongas and included a roundtable discussion which involved representation from the Massachusetts legislature (Representative Mark Roosevelt and Senator Michael Barrett), business (Mr. Jack Rennie, Pacer Systems, Inc.; Mr. Martin Kaplan, Hale and Dorr; Mr. John H. Hobbs, Jennison Associates Capital Corporation), the media (Ms. Muriel Cohen, The Boston Globe, and Ms. Jan Stager, WHDH-TV), and practicing teachers (Ms. Elaine Hall, Quabbin Regional High School, and Mr. Dana Dunnan, Masconomet High School). The Forum was videotaped on 6 June 1992.

THE ESTABLISHMENT OF *PROJECT ARCHIMEDES*

Unlike the above individual outreach initiatives which have been developed on a largely volunteer basis, the institutional initiatives identified earlier require an institutional structure with a range of functions and responsibilities. The Council on Primary and Secondary Education serves as the body responsible for the execution of the above recommendations. Quality control will be provided not only by the Council itself, but by an External Advisory Committee which will include MIT alumni and others from beyond the immediate MIT community. When the intellectual and fiscal resource base that is required is in place, the Council proposes to launch this effort under the name of *Project Archimides*. Our goal is ***to move a nation***.

R.M. LATANISION

Facilities Use Committee

Reporting to the Provost, 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; Gayle Fitzgerald, Manager of Conference Services; Brenda Generazio, Senior Staff Assistant, Office of Government and Community Relations; Susanna Hinds, Director of Campus Activities; Mary Morrissey, Director of the Information Center and Special Events; ; Paul Parravano, Assistant for Community Relations; and Phil Walsh, Director, Campus Activities Complex.

Several changes in committee membership occurred this year. Robert Cunkelman, Staff Mechanical Engineer, Physical Plant was succeeded by Mary Mullen, Administrative Assistant, Preventive Maintenance; Winston "Pat" Flynn, Associate Registrar, Facilities and Scheduling was succeeded by Bonny Kellerman, Associate Registrar, and Mary Callahan, Assistant Registrar, Schedules; Michael Foley, Manager, Campus Activities Complex was succeeded by Karen Nilsson, Assistant Director, Campus Activities Complex; and Patricia Murphy, Administrative Assistant, Campus Activities Complex was succeeded by Zina Queen, Event Coordinator, Campus Activities Complex.

During the 1991-92 year, in addition to a number of smaller meetings, the Institute hosted meetings of the Women's Action Alliance Equity Program, the AIFS Exchange Program, the American Institute of Aeronautics and Astronautics, the English/Japanese Exchange Program, the College and University Auditors, the New England Society for Group Psychotherapy, and the Massachusetts College Personnel Association. In addition the Institute hosted the Annual Whitehead Institute Symposium, the Boston Psychoanalytic & Institute Symposium, a Workshop on NC Dosimetry, an Electronic Imaging Seminar, the Massachusetts Future Problem Solving Bowl, the Device Research/Electronics Materials Conference, the Technology Transfer Conference, the Abduction Study Conference, "the Games of Ancient Grease" fund raiser for WBUR, a church carnival on behalf of the St. Constantine and Helen Greek Orthodox Church, and the President's Council of Advisors on Science and Technology Public Meeting.

Stephen D. Immerman

MIT Industrial Performance Center

INTRODUCTION

The MIT Industrial Performance Center is an Institute-wide center for the study of productivity and industrial performance. Its researchers seek to develop fresh insights into key determinants of industrial performance and to recommend practical new approaches for strengthening public policies, business strategies, and engineering practices concerning these important issues.

BACKGROUND AND GOALS

For the best part of two decades, the real incomes of much of the American workforce have stagnated. The single most important reason for this has been the weak productivity performance of the U.S. economy. Productivity growth in the United States remains the slowest of all the major industrialized countries, and is a serious threat to the nation's future prosperity.

The MIT Industrial Performance Center was established in the fall of 1991 with the assistance of a major grant from the Sloan Foundation to continue and deepen the study of industrial performance begun by the MIT Commission on Industrial Productivity, whose final report, *Made in America: Regaining the Productive Edge*, was published in 1989. The mission of the center is to conduct research and to create new educational opportunities with the objective of understanding better and improving industrial performance, in the United States and elsewhere. The center's conception of industrial performance encompasses productivity, quality, flexibility, new product and process development capabilities, organizational innovations, human skills and mastery of productive processes, and command of strategic technologies. The center seeks to further the understanding of systems of industrial production through the search for new principles and the development of useful new techniques and models of performance. Center researchers will go onto the shopfloors and into the offices and laboratories of industry in the United States and abroad in order to learn directly about current problems of productivity and competition and to discover new and more effective ways of organizing people and technologies, at the firm, industry and national levels.

A key objective of the Industrial Performance Center is to develop new working relationships with industry and government, to provide new forums for discussion of practical strategies and policies, and to help build a national community of scholars and practitioners concerned with problems of productivity and industrial performance.

RESEARCH PROGRAM

The center's researchers are drawn from the Schools of Engineering, Management, and Humanities and Social Sciences, and bring a broad range of disciplinary perspectives and methods to bear. A central focus of the center's research is the transition to new, more flexible systems of production now underway in a wide range of industries throughout the industrialized world. The new production systems are characterized by greater flexibility in the workplace, by more rapid shifts in consumption patterns, by increasing customer demands for variety, quality, and service, and by the globalization of sourcing and marketing. This transition is presenting a host of complex new challenges to business firms, to labor, to governments, and to educational institutions at all levels. Research projects begun within the past year include:

Information Technology and Productivity

This project seeks to understand the relationship between information technology (IT) and productivity through a combination of careful field-based observation, accurate measures of IT's impacts, and rigorous models of the principal phenomena. The goal is not only to diagnose the immediate causes of the 'productivity paradox', but in the longer run to enhance our understanding of information technology's impact on the organization of work, providing the basis for improved productivity and competitiveness. During the past year, progress has been made on each of the three principal components of the project. By listening carefully to managers' concerns and developing an understanding of how the technologies are actually being used, the investigators have used the first round of field research to develop empirically-relevant hypotheses, amongst which are: (1) conventional output measures underestimate the true impact of IT, (2) lags between expenditures and results bias the findings of previous studies, (3) IT is used to redistribute 'rents' (both within and between firms), instead of to create new value and (4) the intangible nature of IT's direct outputs and its relative newness make it particularly subject to mismanagement and 'agency' problems. Model building and theory development are continuing in parallel. A weekly seminar series around the theme of IT productivity was held during the academic year. Several working papers have been prepared.

Principal Investigator: Erik Brynjolfsson
Other Faculty Involved: Geoff Brooke and Kiran Verma

Comparative Industrial Relations/Human Resources
The objective of this project is to carry out comparative research in ten OECD countries on the impacts and implications of changes in industrial relations/human resource practices concerning work organization, compensation schemes, skill formation, corporate governance, and job mobility/security. The project team includes scholars from each of the ten countries and is led by the MIT participants. An initial project meeting was held in the summer of 1991. Based on that meeting, a two phase project structure was agreed on, with phase I involving preparation of national papers designed to further refine and apply the analytical framework and phase II involving more detailed cross-national studies of particular industries. Phase I papers are now being drafted by the country teams in accordance with a common research protocol prepared by the MIT group. Planning is already underway for the field research for one or more industry studies to be carried out during the coming year. The first such study will be on the telecommunications industry. Partial funding for the project is being provided by the OECD.
Principal Investigators: Michael Piore and Thomas Kochan

Performance Measurement
The motivation for this research is a converging body of evidence, originating in several quite different disciplines and intellectual traditions, suggesting that many long-standing and widely-used measures of industrial performance -- at the level of individuals, operational units, firms, industries, and even national economies -- are no longer reliable proxies for actual performance, and that this increasingly imperfect match between measures and outcomes is in some cases a significant proximate cause of competitive weakness. The first major milestone was a workshop to which researchers from seven industry research centers recently established by the Sloan Foundation were invited to discuss the problem of performance measurement from various industry perspectives.
Principal Investigators: Richard Lester and Thomas Kochan

The Global Process Equipment Industries
Work has begun on a new study of the global processing equipment industries. The project has three components. The researchers will (1) study the factors that influence the design and choice of processing equipment and factory architectures; (2) study customer-supplier relationships and equipment sourcing policies, and how these affect competitive advantage through the use of proprietary process technology; and (3) try to quantify the extent of positive externalities present in the process equipment industries, and to understand how different governments and firms in Europe, Asia, and North America have tried to internalize existing externalities in these industries and document the relative advantages of the different approaches. Initially, three types of process equipment will be studied: machine tools used by the automobile industry; surface mount equipment used in circuit board assembly; and process equipment used for semiconductor manufacture. The methodology will be primarily field-based, but guided by knowledge and conceptual foundations in the fields of operations management, economics, and engineering. The researchers plan to coordinate their efforts with several of the Sloan Industry Studies.
Principal Investigator: Charles Fine; Other Faculty Involved: Thomas Eagar and Paul Krugman

Domestic Institutions, Free Trade and the Pressures for National Convergence: US, Europe, and Japan
Preliminary work has begun on this project. The first major milestone will be a conference of international scholars to be held in February 1993. The conference will examine the role and limits of convergence of national industrial policies and domestic business practices in international industrial competition. The purpose is to lay out the current state of knowledge about these issues, and the conference will be an important step in organizing the MIT research enterprise. The Rockefeller Foundation has agreed to make its Bellagio Conference Center available for this event.
Principal Investigators: Suzanne Berger and Ronald Dore

Design Process Study
Work began earlier this year on a new comparative study of the engineering design process in different industrial and cultural contexts. Through a research process which will include structured interviews with design practitioners, the project will study cross-national and cross-industry variations in design approaches and consider the role of cognitive, historical and other factors in explaining these variations.
Principal Investigators: Fred Kofman, Richard Lester and Michael Piore

U.S.-Japan Quality Management Comparison
A collaborative research project has been initiated with the Center for Quality Management (CQM), a consortium of 24 New England companies in the high technology, manufacturing, health care and construction industries that was founded in 1990 to share knowledge about and advance the state of Total Quality Management. The purpose of the project is to make a detailed study of Japanese and US quality management practices by comparing the quality programs of Deming and Baldrige Award winners. The Japanese Union of Scientists and Engineers (JUSE), which helps to administer the Deming award, is also cooperating in this research.
Principal Investigators: Thomas Lee, Richard Lester, Shoji Shiba and Dave Walden (Bolt, Beranek and Newman)

EDUCATIONAL ACTIVITIES

A key objective of the Industrial Performance Center is to develop new educational resources that will give our students a deeper understanding of how problems of industrial performance appear from the perspective of real world experience as contrasted with textbook theories; how core theories of disciplines other than their own treat these problems; and how different firms, different industries and different societies organize in different ways to solve them.

During the last year, the Center inaugurated a new doctoral fellowship competition, and two projects to develop new courses have also been launched.

Graduate Engineering Course: "Technologies, Industries, and Nations"

The proposal to develop this course has grown out of the discussions of the 'closed systems' subgroup of the Large Scale Systems faculty committee, led by Joel Moses. The Center sponsored a retreat for the full committee in July 1991. The proposed course is designed to enable the students to develop an understanding of the strategic and organizational context for key technical functions (product and process development, design, manufacturing); to develop an appreciation for the impact of different national cultures and structures on the choice of production systems and on performance outcomes; and to gain insights into what it takes for firms to make successful transitions from one type of production system to another.

Principal faculty: Richard Lester and Joel Moses
Other faculty involved: Bob Brown, Don Clausing, Gene Covert, Amedeo Odoni, Tom Magnanti, Dan Roos and Dave Wormley

Undergraduate Course on International Manufacturing Practices and Policies

This course will be designed particularly for the growing number of MIT undergraduate students who intend to pursue science and technology internships in Japan and Europe. The course is intended to help these students observe intelligently and think systematically about cross-national differences in national policies, industrial structures, cultural attitudes, and educational practices and the implications of these differences for industrial performance.

Principal faculty: Suzanne Berger, Richard Lester and Michael Piore

Doctoral Fellowship Program

In order to create opportunities for MIT doctoral students to pursue independent thesis research in fields related to the objectives of the Industrial Performance Center, a doctoral fellowship program was launched this Spring. Three doctoral awards have been made for the forthcoming academic year. The projects are: *Technology, Work Reorganization, and Productivity Growth in Telecommunications*, Rosemary Batt (Sloan School of Management); *The Restructuring of Chicago's Small Firm Metalworking Industry: Vertical or Horizontal Production Networks*, Lynn McCormick (Department of Urban Studies) and; *Organizational Strategies in Biotechnology: Theory and Evidence*, Diego Rodriguez (Department of Economics).

OTHER ACTIVITIES

Faculty Seminars

During the academic year, the center sponsored a series of faculty seminars which have provided a new forum for faculty drawn from a dozen departments across the Institute to discuss problems of industrial performance.

Sloan Industries Studies

The Center plays an important role in helping to develop intellectual connections and research collaborations among the *Sloan Industry Studies*. The principal contribution in this area to date has been to organize the Workshop on Performance Measurement, which took place in Berkeley in April. The Center will continue to play a role in organizing future meetings, promoting information exchange, and proposing and helping to carry out collaborations on cross-cutting research issues.

ORGANIZATION

The Industrial Performance Center is an MIT-wide unit, located administratively within the Office of the Provost. Its Advisory Council is chaired in annual rotation by the Deans of the Schools of Management, Engineering, and Humanities and Social Sciences. Its staff consists of the director, Richard K. Lester, the assistant to the director, Betty Sheridan, and the administrative assistant, Anne Flaherty.

RICHARD K. LESTER

ASSOCIATE PROVOST

I assumed my present position on February 1, 1992. This report summarizes some highlights of my activities to date.

Academic Responsibility

The Committee on Academic Responsibility, which I chaired, submitted its report in April. This report was discussed by the Faculty in May. I have been moving to implement its recommendations in several areas. The report of the Committee was widely distributed within MIT and nationally to other universities, government agencies and members of Congress. We have received several requests to reprint the report from universities who wish to use it in their educational programs and in the development of their own procedures. I was also a member of the National Academy of Sciences Committee on the Responsible Conduct of Research, whose efforts overlapped substantially with the work of the MIT Committee. In connection with these two activities I have made presentations to scientific societies, at universities, in press briefings, and in meetings with Federal agency staff and management charged with carrying out responsibilities in this area.

At the request of the Committee, the Dean of Science established a School committee on education in research ethics. This committee made recommendations for educational programs for departments within the School of Science. Dr. Stephaine Bird, Assistant to the Associate Provost, has been working with individual departments in both the School of Science and in Whitaker College to plan and carry out such programs. Many of these departmental activities are modeled after the extremely successful retreat that was held by the Whitehead Institute last year. At this meeting, effective use was made of scenarios to stimulate discussion between faculty, postdoctoral researchers and graduate students. These scenarios were published in the Committee report and have received wide attention at MIT and at other universities. Stephanie is also visible on the national scene as a professional in the field of research ethics. For example she has organized a AAAS symposium on Education in Research Ethics for the upcoming Boston Meeting and represents MIT in several national consortia dealing with research ethics. I have also met with Engineering Council to discuss such departmentally based programs. For several years, the School of Engineering has offered courses dealing with professional ethics upon which such activities can build.

The issues of academic responsibility and the ethical conduct of research relate to the more general question of academic honesty. A lively discussion of this issue is taking place within the MIT student body, partly as a result of the efforts of the Committee on Discipline to publicize the outcome of its deliberations. I have participate with student government in discussions of a possible honor code and/or other ways in which this issue could be kept on the agenda of MIT faculty and students, and I have been active in the planning of an MIT Colloquium to be held on this topic in the Fall.

International Issues

I have been moving to implement the recommendations of the Skolnikoff Committee to provide a focal point within the Office of the Provost for international issues. I have met with a variety of groups and individuals on various international issues and will soon reconstitute the Faculty Committee on International Commitments to spend less time reacting to specific proposals and more time reviewing MIT's international commitments more broadly. Committees have also been formed to examine specific regional issues. One such committee will consider broadly the issues of MIT's relations in Europe, with universities, industries and governments. A second committee will deal with MIT's relations in the Far East. These will become subcommittees of the central faculty committee.

I am chairing a joint Faculty, Administration and Corporation committee, established by the President and the Chairman of the Faculty, to examine issues related to the admission of international students. The charge to the Committee is to: "review the current situation and historical trends regarding the international character of the MIT student body. Consider the role of international students as alumni, and as contributors both to their home countries and to the US. Consider the appropriateness of policies to set the percentage of international students both graduate and undergraduate. Assess current admission, tuition and financial aid policies for international students, both graduate and undergraduate. Estimate the effects of such policies on our ability to attract excellent international students. Review recent efforts to encourage fund raising from international graduates. Present recommendations to the Faculty and Administration for their consideration."

Council On Federal Relations

The Council on Federal Relations, composed of members of the Faculty and Administration has been formed to advise MIT on a variety of issues related to our relations with the Federal Government. We wish to ensure that the experience and expertise of MIT and its faculty can be brought to bear on a variety of national issues, to contribute to sound Federal policies based on science and technology and to promote the health of the research/education enterprise focused on science, technology and their applications. With the establishment of the MIT Washington Office, the Council seeks to make effective use of our Washington presence, to interact with and provide expertise to Congress and the Executive Branch on specific issues, and to involve the faculty in the setting of priorities for MIT's Federal relations. Members of the Council and other members of the MIT community have been called upon on a variety of occasions to interact with Congress and its staff and members of the Executive Branch. For example, following up on the work of the Skolnikoff Committee, whose report "The International Relationships of MIT in a Technologically Competitive World" was recently published, a briefing was held in Washington D.C. for staff members of several committees in the Senate and House. MIT participants included Gene Skolnikoff, Richard Lester, Eric Johnson, Jack Crowley and John Preston, who made presentations about various aspects of the issue. A lively discussion ensued dealing with the relation between university research and US industrial competitiveness, the access of foreign corporations to MIT faculty research, the two-way flow of information in such interactions, technology licensing and the education of international students.

SHEILA E. WIDNALL

ASSOCIATE PROVOST FOR INSTITUTE LIFE

MIT Educational Talent Search

INTRODUCTION

The Office of Educational Opportunity Programs was created in January of 1992 to organizationally locate both the MIT/Wellesley Upward Bound and MIT Educational Talent Search Programs. MIT has operated the Upward Bound Program since 1966 and began operation of the Educational Talent Search Program in September of 1991.

Upward Bound and Educational Talent Search are two of six U.S. Department of Education: Special Programs For Students From Disadvantaged Backgrounds created under the Higher Education Act of 1965.

The goal of these Programs is to provide college admission and preparatory information, academic support, counseling, career information, and college and career exploration opportunities to the economically and/or educationally disadvantaged youth of Cambridge.

To a large extent, the development of both Programs was 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. Educational Talent Search and Upward Bound, through their year-round academic support and counseling, represent just such an intervention.

It has been long 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. While the Educational Talent Search Program is too new to report significant results, the Upward Bound Program continues a lengthy record of success (90+% college enrollment of graduates and 70% retention of participants annually) achieved during its 25 year existence through the application of Kurt Lewin's theory and careful attention to the impact of Program expectations.

Finally, since much of what students think they can achieve has been directly related to what others think they can accomplish, 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 Programs are able to exert such an influence upon the participants that their academic persistence grows and results in increased postsecondary enrollments.

MIT EDUCATIONAL TALENT SEARCH

The MIT Educational Talent Search Program is a year-round, co-educational, program, located on campus, designed to assist participants, in grades 7-12, who live and/or attend school in Cambridge, to continue in a course of education leading to graduation from secondary school and enrollment in postsecondary educational programs. Currently in its first year, the Program is funded to serve 400 young men and women from disadvantaged backgrounds.

The following is an overview of the Program's year-round operation:

ACADEMIC YEAR PROGRAM
The academic year program is designed to inform, assist and support participants during the school year through a number of after school, evening and weekend activities:

Tutorials & Study Skills
The Educational Talent Search office is open for supervised study, on a drop-in basis, four days a week: Monday & Thursday from 3:00 p.m. to 6:00 p.m. and Tuesday & Wednesday from 3:00 p.m. to 8:00 p.m.. Staff are available to provide assistance with homework or provide tutorial assistance in content areas. Students are assigned to group or individual study skills workshops on an as needed basis.

Instruction & Workshops
The Program offers programmed instruction in Mathematics and Language Arts to supplement instruction received by participants. Additionally, workshops are offered to provide more specific support or to address special interests (e.g., SAT preparation, Word Processing, Computer Games, Poetry, etc.).

MIT/Wellesley Upward Bound Program

Counseling
In an effort to assist participants as they attempt to cope with problems of an academic, social, family or personal nature, the Program offers counseling support and referrals in the areas of school guidance, college and career, and personal adjustment.

Information Dissemination and Exploratory Activities
In an effort to provide both participants and their families with information relative to college; choice, preparation, and the admission and financial aid processes, the Program held two parent information nights, took participants to three local College Fairs and sponsored 10 college visits. In addition, the Program hosted a bi-monthly career speaker series and (5) career exploration trips.

Cultural and Recreational Activities
The Program provided 10 field trips for the purpose of increasing the intellectual, social, and cultural development of the participants. Some of the sites visited were; the Museum of Science, the Computer Museum, the N.E. Aquarium, The Museum of Fine Arts and the Basketball Hall of Fame. In addition, the Program visited several points of interest, i.e., libraries, museums and laboratories, on campus.

SUMMER PROGRAM
The summer program provides both academic instruction to 65 seventh and eighth grade participants and a continued college information and exploration program to participants in grades 9-12.

The summer academy for seventh and eighth grade students provides classes in Mathematics, Language Arts, General Science and Social Studies. The classes, held Monday-Thursday, are designed to provide both developmental assistance and enrichment and are taught by experienced teachers from the greater Boston area. Field trips are taken every Friday to local points of interest.

Since many of the participants in grades 9-12 hold summer jobs, the Program provides continuing support through dissemination of information about area college fairs, hosting three career nights and sponsorship of four college visits.

MIT/WELLESLEY UPWARD BOUND

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-fifth 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.

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. Also, participants may request or be assigned to tutorials whenever the need arises. Each participant is required to enroll in a Mathematics course, an English course and an elective course (Social Studies or Science). Science electives include; biology, chemistry, physics and computers while Social Studies address United States, Black and World Histories. The Mathematics courses range from arithmetic to calculus and Language Arts courses cover basic English and grammar through research paper writing and literature. Lastly, due to an agreement with the Cambridge Public Schools, students may receive summer school credit for failed courses taken for review.

ACADEMIC YEAR PROGRAM
The academic year program located at MIT, while somewhat less intense due to our after-school operation, is as equally important in the educational development of participants. Building upon the motivation and enthusiasm developed during the summer, the academic year program is designed to assist and support the participant while in school. To accomplish this task, the following programs, staffed primarily by MIT and Wellesley College students when appropriate, (We continually strive to maintain MIT and Wellesley College students' participation through our continued involvement as a pre-practicum site for the Wellesley College Teacher Certification Program and through various outreach efforts.) have been developed:

Tutoring and Study Skills
The Upward Bound office is open for study, on a drop-in basis, four days a week: Monday and Thursday from 3:00 to 6:00 pm and Tuesday and Wednesday 3:00 to 8:00 pm. Tutors are available to assist participants with homework problems in addition to meeting individuals and/or small groups for specific content area tutorials.

Classes and Workshops
The Program offers classes in Mathematics and Language Arts to supplement the instruction received at the target school. Also, academic workshops are offered to address more specialized participant needs (e.g., SAT preparation, Computers, Foreign Language, etc.).

Counseling
In an effort to help participants cope with the myriad of problems; academic, social, family, etc., the Program offers counseling support in the areas of guidance, college, career and personal adjustment.

Cultural and Recreational Activities
The Program provides numerous field trips which have as their purpose, the intellectual, social and cultural development of the participants. Some of the trips have visited; the Museum of Science, the New England Aquarium and the Computer Museum.

COLLEGE REPORT: CLASS OF 1992
One hundred percent of the Program's graduating seniors have enrolled in the following institutions: Boston University, Fitchburg State College, Northwestern University, Penn State University, Pine Manor College, Salem State College, University of Illinois, Virginia State University.

RONALD S. CRICHLOW

ASSOCIATE PROVOST FOR THE ARTS

INTRODUCTION

The arts at MIT have completed a strong year with important exhibits at both the List Visual Arts Center and the MIT Museum, and with a strengthened Office of the Arts overseeing Arts Communication, the Council for the Arts at MIT, and Special Programs (including the Artist-in-Residence Program). Following this introduction are the individual reports from these units. In addition to these successes, the arts community at MIT has worked through the Creative Arts Council to prepare a *Report on the Arts*, has become an active participant in the national discussion on arts education, has through the rejection of a grant application to the National Endowment for the Arts (NEA) become a major player in the national debate on federal funding for the arts, and continued its lively efforts on behalf of fund-raising for the arts at MIT.

REPORT ON THE ARTS

The Creative Arts Council (CAC) in collaboration with the Associate Provost for the Arts discussed, drafted, and completed a report to the MIT community on the changes in the arts at MIT in the three years since the establishment of the position of Associate Provost for the Arts and the Office of the Arts in the autumn of 1989. The report also followed by five years the Report of the Ad Hoc Committee to Review the Creative Arts at MIT of 1987, which set many of these changes in motion. As the earlier report had established the status of the arts and arts programs on campus in 1987, the new report sought to examine the progress that had been made in the five intervening years and to set the path for the future.

The report was prepared in draft by the Associate Provost and discussed by CAC at successive meetings. Members of CAC then took the drafted report to their individual units for further discussion, and the Associate Provost met directly with the Humanities and Social Science Council and Architecture and Planning Council. The final 68-page report, which is a product of the full MIT arts community, sets the campus-wide mission for the arts at MIT and describes the current status of arts programs within this mission. It was presented to Academic Council in April, 1992, and is now being distributed to relevant offices at MIT. The report is also available in the office of the Associate Provost for the Arts.

ARTS AND EDUCATION

The Office of the Arts has in the past year actively entered the national discussions on education and the role of the arts in education. The Associate Provost published an article in the *Aspen Institute Quarterly* entitled *"Why Study the Arts -- Along with Science and Math?"* that addressed the lack of any mention of the arts in the America 2000 Plan; since publication this article has seen wide national distribution. The Associate Provost also participated in two national conferences concerning education at both the K-12 and undergraduate levels -- the Asheville Institute on General Education (sponsored by the Association of American Colleges) and a working conference entitled *Arts and Education: a Partnership Agenda* (sponsored by the NEA) -- and joined a national working group (co-sponsored by The Kennedy Center and the J. Paul Getty Trust) to prepare specific recommendations for Secretary of Education Lamar Alexander at the request of the Department of Education "to emphasize the importance of arts education in American schools and to help merge arts education into American 2000 community-based school improvement efforts." The working group will address how the arts are essential as individual subjects to the education of the whole person, and also, through the exercise of discipline and imagination, provide a working tool to improve general education at all levels.

FEDERAL FUNDING FOR THE ARTS

The past year was marked by a major national controversy aroused by the rejection of a grant application submitted by the List Visual Arts Center to the NEA by the Chairperson of the endowment after the application had been recommended by the peer review panel and the National Council on the Arts. The NEA did not provide adequate, written reasons for this rejection either publicly or privately, but the action was widely believed to relate to statements made by the Chairperson one week before the decision was announced that the NEA would deny funding to projects that contained sexually explicit images or were simply "difficult." The exhibition proposed by the List Center, entitled *Corporal Politics,* examines the prevalence of the body fragment as both theme and content in contemporary sculpture. Reaction to the

decision of the NEA Chairperson to override the recommendations of a merit-based, peer review process was swift and dramatic. The Beacon Press of Boston withdrew its current NEA application, and the Artist Trust of Seattle refused its two NEA grant awards. Stephen Sondheim and Wallace Stegner both refused a National Medal for the Arts. One of the NEA's peer review panels suspended its deliberations following the announcement, and another resigned without deliberating at all. A detailed chronicle of these events, including images of some of the artwork, was prepared by Mary Haller, Director of Arts Communication, and distributed widely to the MIT community on and off campus, which helped to redress the rumors and misstatements that had been circulated by some members of the media.

The issues raised by the rejection of this application are far more important than the impact on the specific exhibition. At stake is the free investigation of ideas and the role of merit review by experts in the field, not only in the NEA but within all federal funding agencies and the Congress. The use of criteria other than merit, decisions made through processes other than peer review, and an increasing call for projects that reach out to the widest possible audience are undermining processes that have ensured excellence in the federal funding of academic and artistic projects for decades. The Office of the Arts has begun and will continue to argue for merit-based peer review in the arts by working directly with the NEA and by planning national forums on these issues at MIT.

FUND-RAISING

Fund-raising for the arts is overseen by the Associate Provost for the Arts with the advice and assistance of Lucy Miller, Associate Director of Major Gifts, and Glenn Billingsley, Development Officer for the Arts. A significant portion of our effort is directed through the Council for the Arts at MIT, and a separate report from the Director Mark Palmgren follows. Other initiatives are made through individuals not associated with the council, foundations, and public funding.

Council for the Arts

Gifts to the Council for the Arts at MIT (CAMIT) were down this year in both the total amount and the number of contributors. This year 40 members contributed $164,104 compared to last year's total of $224,110 from 52 members. Because of this shortfall, the budget needed to be reduced at mid-year, cutting the amount the council could give to programs. Non-member contributions to CAMIT were also lower, dropping to $22,855 from 22 donors from FY91's $39,995 from 24 donors. This apparently bleak picture was counterbalanced, however, by a stunning increase of donations from CAMIT members to specific arts programs on campus apart from the council. In FY91 seven CAMIT members gave $30,540 to such programs; this year ten members gave $283,209, including a gift of $200,000 as the first payment of a five-year $1 million pledge from Vera List to establish an endowment at the List Visual Arts Center. Total contribution to CAMIT plus other arts contributions by CAMIT members thus exceeded last year's by a significant margin: $470,187 in FY92 compared to $294,645 in FY93.

Other Giving

In addition to CAMIT giving, the List Visual Arts Center, the MIT Museum, and the Office of the Arts received a total of $251,050 from various sources, including individuals, foundations, consulates, and public funds. Gifts of appraised gifts-in-kind totaled $288,000. In FY92, therefore, total annual contributions to the arts (not including pledges) were maintained at about $1 million.

Facilities

In our continuing effort to improve arts facilities (FY90: new visual arts facilities; FY91: new dance floors), this year's success was the opportunity to move forward with plans for music practice rooms in Building 4 adjacent to current music classrooms. The $150,000 funding was made possible by CAMIT members, including Martin Rosen '62 and Leonard Bezark, Jr. '49. We expect these renovations to be completed during spring semester '93.

Artist-In-Residence

Our continuing fund-raising efforts have assisted the continued growth and success of the Artist-In-Residence Program (A-I-R), a separate report on which follows by Maureen Costello, Director. This program was supported in part by a grant of $10,000 from the Knight Foundation and by the first payment of a five-year $50,000 pledge by CAMIT member Andrew Silver '64.

Faculty Artists

In addition to supporting the residencies of outside artists, it is part of the mission of the Office of the Arts to support and showcase MIT's extraordinary arts faculty. This year CAMIT helped support a new work by dancer Beth Soll and composer/laser artist Paul Earls. A-I-R supported the performance on campus of *A Company of Angels* by playwright Alan Brody, and the office of the Associate Provost supported performances by five MIT composers at Boston's first New Music Harvest: Peter Child, Edward Cohen, David Epstein, John Harbison, and Evan Ziporyn.

AFFIRMATIVE ACTION

The offices under the supervision of the Associate Provost for the Arts continue to have very strong representation of women on their staffs and no minorities. Of thirty-three employees, twenty-three are women, and the one new hire this year was a woman replacing a woman. The directors within the Office of the Arts have scheduled a meeting to discuss the *Presidential Task Force on Career Development of Minority Administrators at MIT*, to develop common strategies for making sure minority candidates are informed of our job vacancies, encouraged to apply, given the opportunity to interview, and hired.

The Office of the Arts has already been very successful in creating programs that represent the cultural diversity of MIT and the community. For example, more than fifty percent of the artistic residencies involved artists of color from African American, Hispanic and Asian backgrounds, and the MIT Museum has developed important educational links to the Cambridge school system. These programs are discussed in more detail below.

ELLEN T. HARRIS

Office of the Arts

As arts programs expanded over the past year, Arts Communication worked to support and publicize the activities and achievements of MIT's arts community, and to increase awareness of programs and opportunities within the Office of the Arts. Through the combined efforts of Arts Communication and MIT's arts community, the Institute's artists and arts-related events achieved greater visibility both on-campus and at local and national levels.

Significant events and accomplishments included the following:

Internal (MIT)

Twenty feature Arts Pages and eight Month-At-A-Glance Arts Pages were produced by Lynn Heinemann (writer) and Susan Cohen (designer) in the Office of the Arts and published in Tech Talk. Poster copies of each Arts Page were distributed widely on and off campus, and distribution was increased to include local hotels and more members of the general public. Information from each Arts Page was also made available through MIT's TechInfo.

The Arts Page continued to develop into a "voice" for the arts community at MIT and a comprehensive source of arts information: arts event listings from Tech Talk's Institute Calendar were incorporated into the Arts Page, six pieces by MIT guest writers were included in Arts Pages, and there was a marked increase in the number of departmental representatives who turned to the Office of the Arts for coverage of their arts-related events. Five student photographers were hired to document campus arts events for the Arts Page and other on-campus publications.

Seven feature articles and photographs on arts-related news and events were published in Tech Talk's general spaces.

Increased use was made of previously-underutilized communication venues at MIT, including drop posters, Student Center Information Desk, LSC slides, departmental newsletters, WMBR, MIT Cable, and halls and dormitories. A feature story on the Artist-in-Residence Program was written for a new newsletter produced by the Department of Humanities and Social Science. Maintenance continued of the "Arts at MIT" bulletin board in Lobby 7 and the weekly "Arts Hotline" (253-ARTS).

Communication between members of ArtsNet, now a group of over seventy campus arts representatives, was facilitated by the introduction of an e-mail address connection (artsnet@media.mit.edu). Information-sharing between individual ArtsNet members and the Office of the Arts increased as members became more aware of the OA's communication resources and services.

General information on the arts at MIT was updated for various institutional publications, including the MIT Bulletin, Facts Book, and UROP Guide. Information on the arts at MIT was also written for new orientation materials produced by the Personnel Office, and for the new MIT campus map.

IAP activities included over 70 arts-related programs, workshops, and performances. Listings of arts events occuring during IAP were prepared by Arts Communication and distributed throughout campus and to selected off-campus locations.

The "Arts at MIT" brochure was distributed and made available by various on-campus departments, including the Campus Visit Office, Personnel Office, Student Center Information Desk, Freshman Admissions, Alumni Offices at MIT and in New York and Washington, D.C., and arts-related programs and departments.

National and Local

An article by Associate Provost for the Arts Ellen T. Harris on "Why Study the Arts--Along With Math and Science?" was published in the Aspen Institute Quarterly and received enthusiastic responses from arts and education leaders across the country. Copies were distributed at a number of national arts and education conferences, and to MIT's Creative Arts Council, Academic Council, and Committee on K-12 Education. Portions were published in the Industrial Liaison Program's *The MIT Report* and quoted by MIT President Charles Vest in a speech to the National Science Teachers Association.

Director of Arts Communications Mary Haller represented MIT at Arts Advocacy Day in Washington, D.C., where she attended an advocacy training session and panel discussions on legislative issues affecting the arts, visited the offices of Senators Edward Kennedy and John Kerry and Congressman Joseph Kennedy to encourage their continued support of the arts, and discussed MIT's arts programs and initiatives with artists and arts professionals across the country. In addition, personal contacts were made with representatives from the National Endowment for the Arts and National Public Radio.

The denial of funding by National Endowment for the Arts acting chairman Anne-Imelda Radice for an exhibition by MIT's List Visual Arts Center generated unprecedented and far-reaching national press attention through print and electronic media. A contribution of $10,000 to the LVAC by the Boston-based rock group Aerosmith gave the story a new dimension of public and media interest; a press gathering held at the LVAC to announce the donation was attended by reporters and photographers from Associated Press, *Time Magazine*, the *Boston Globe*, *Boston Herald* and *Boston Phoenix*, the three local television networks, New England Cable News, and MTV, all of whom ran headline stories on the event.

Since the grant rejection was announced on May 12, 1992, over 200 articles and editorials have been printed about the controversy in publications including the *New York Times*, *Washington Post*, *Chicago Tribune*, *Los Angeles Times*, *USA Today*, *New York Newsday*, *Washington Times*, *San Francisco Examiner*, *Wall Street Journal*, *Village Voice*, *Philadelphia Enquirer*, *The Chronicle of Higher Education*, *Newsweek*, and a number of other newspapers and magazines in New England and across the country. The controversy generated publicity on national television and radio as well, with features on National Public Radio and Nightline, and stories/interviews on stations in New England, Chicago, San Francisco, Houston, and Miami.

The "Arts at MIT" brochure was distributed at various local and national events and conferences, including an Open House at the Wang Center for the Performing Arts, press gatherings sponsored by Cambridge Discovery and the Greater Boston Travel and Convention Bureau, Arts Advocacy Day in Washington, D.C., and a conference on "Arts and Education: A Partnership Agenda," sponsored by the National Endowment for the Arts.

Appearances by MIT Artists-in-Residence and visiting artists received press attention in the *Boston Globe*, *Boston Phoenix*, and other local and internal publications. The appearance of novelist Toni Morrison as the 1992 William L. Abramowitz Lecturer drew overflow crowds and generated announcements and articles in local papers including the *Boston Globe* and *Bay State Banner*.

Arts Media Calendars were produced and mailed monthly to 240 members of the electronic and print media.

MIT arts events were included in the 1992 Boston Festival (February 14-18), a new annual celebration promoting Boston's cultural offerings.

MARY L. HALLER

ARTIST-IN-RESIDENCE PROGRAM

In its second year, the Artist-In-Residence Program developed and coordinated more than a dozen residencies with nationally and internationally acclaimed performing, visual, and literary artists. Through extended master classes, lecture-demonstrations, performances, workshops, and studio critiques, residencies provided students and faculty with substantial curricular-based interaction with the individual artists and companies. More than fifty percent of the residencies involved artists of color in programs which affirm the cultural identity and diversity of the MIT community. Residencies were developed in close collaboration with the faculty to complement course goals. Several interdepartmental programs were implemented; and in many cases MIT staff and students participated in the development of the program. The following highlights some of the 1991-1992 residencies:

I Wayan Sadra, Composer and Performance Artist. Music Department, Professor Evan Ziporyn.
Workshops and lecture demonstrations on Balinese gamelan and vocalizing techniques. Collaboration with American Gamelan Institute at Dartmouth and the Museum School, Boston.

Jerry Butler, Actor. Theater Arts Department, Professor Alan Brody. The MIT Chuckawalla Valley State Prison Arts-in-Corrections Project.
On-going video letter conversations between eight pairs of MIT minority students and Chuckawalla inmates. Artist videotaped interviews between bicoastal students and inmates on issues such as institutions, racism, and families. Butler worked at the Institute and in the prison.

Rosa Marquez and Antonio Martorell, Theater and Graphic Artist Team from Puerto Rico. Theater Arts Department, Professor Alan Brody.
MIT students and multigenerational members of the Cambridge and Boston Hispanic community transformed a Visual Arts Program studio during IAP and created a setting for an original theater work about food and shelter. Documentary of the process to be aired on WGBH "La Plaza" in 1993. Marquez returns as Theater Artist-in-Residence in 1992-93.

Valerie Maynard, Visual Artist. Collaboration with Visual Arts Program, Professor Ed Levine and MIT Museum, Warren Seamans, Director.
Artist and students explored the issue of apartheid through two-week sculpture workshop. Student sculpture was included in Compton Gallery exhibit of the artist's prints and sculpture entitled *No Apartheid Anywhere.*

Toni Cade Bambara, Writer and Filmmaker. Program in Women Studies, Professor Ruth Perry and the Office of the Dean of Students, Dean Ayida Mthembu.
To begin a spring semester examination of the contribution of African American women to the arts, Toni Cade Bambara participated in a Black Studies course and other literature courses, showed "The Bombing of Osage Avenue" followed by critical discussion, and gave a reading in the Bartos Theater and stimulated discussion of Black women writers and filmmakers during a week-long residency in February.

Peter Campus, Digital Photographer. A collaboration with the Visual Arts Program, the Center for Advanced Visual Studies, and the List Visual Arts Center.
During the spring semester Peter Campus, a former CAVS fellow, taught digital photography techniques to undergraduate Advanced Photography students. CAVS students explored contemporary issues in the arts, the media, and the environment. The artist's recent work in digital photography was on exhibit in the List Visual Arts Center.

SPECIAL PROJECTS

The 1992 William L. Abramowitz Guest Lecturer: Toni Morrison, Author.
Toni Morrison spoke to the Classof '92 and the public in a lecture entitled "The History of *Beloved* and the Culture of *Jazz*" which addressed an earlier novel, *Beloved*, which Seniors had read as Freshman, and

Morrison's most recent work, *Jazz*. Students participated in a question and answer forum with Ms. Morrison. A multicultural planning committee of faculty, staff, and students developed related programs about the author's work for the Senior Class and the African American Community.

New Music Harvest Fall Festival.
Advisory Board work with New Music Harvest was realized in the first festival of new music in Boston. **Collage New Music** presented a program of works by five MIT Music Department composers: Peter Child, Edward Cohen, David Epstein, John Harbison and Evan Ziporyn.

***Company of Angels* by Alan Brody**
A staged reading of a new work by Alan Brody, Chair of Music and Theater Arts, was held in Killian Hall in December. The New Repertory Theater in Newton will mount a full production of *Company of Angels* during the 1992-93 season.

One Percent Public Art Programs
Policies and procedures for MIT public art projects are in development. In conjunction with the List Visual Arts Center, two public art projects are underway. Work with Mags Harries on the Stratton Student Center will resume in Fall, 1992. Jim Melchert was chosen to design the new Biology Building's 210 foot long ceramic tile and glass mural which will face Ames Street.

Martin Luther King Celebration Committee
Vocalists Semenya McCord and Associates presented *Journey Into The Dream* in Kresge Auditorium.

NEW INITIATIVES
List Foundation Fellowship Program.
Through the generosity of the List Foundation in New York, an annual Fellowship Program in the arts was established. Up to $5,000 each will be offered to one undergraduate and one graduate minority student to pursue work in the performing, visual, or literary arts. The first List Fellows will be awarded in October. Students will work with a MIT faculty advisor and outside artist mentor. The first List Fellows will share their project with the MIT community in the Spring of 1993.

Multicultural Community Collaborations
Several internal and external initiatives were begun to affirm the diversity of the MIT community through cultural programming. Contact with the MIT and Boston Asian communities was established in connection with the List Visual Arts Center exhibition "Fugitive Landings" by May Sun. Collaboration with the MIT Latino community was established through work with Latino student organizations and sponsored trips to the Institute of Contemporary Art to see *El Corazon Sangrante - The Bleeding Heart* and to IBA, Arte y Cultura to attend Latino artists' performances. A collaboration with the New England Conservatory Director of Community Services has been established.

World Music Consortium
A network of university music faculty, non-mainstream cultural institutions, music critics and musicians was formalized to collaborate on short and long term programs with world musicians. Israel "Cachao" Lopez, Cuban bassist, worked with the MIT Festival Jazz Band, the Harvard Jazz Band, and Berklee students.

PERSONNEL
Maureen Costello, formerly director of the "Artists-in-the-Schools" Program for the Cultural Educational Collaborative, a state-wide arts agency of the Massachusetts Cultural Council, assumed the position of Director of Special Programs in July 1991.

-MAUREEN COSTELLO

List Visual Arts Center

The year was marked by several significant developments designed to insure the long-term financial and programmatic stability of the LVAC. Excitement was provided by a dramatic embroilment with a federal arts funding agency over a controversial exhibition proposal. Ten exhibitions of contemporary art and design in the center's three galleries continued to demonstrate the List's visibility and leadership in the field, while a number of important acquisitions were made to the Institute's art collections.

The LVAC applied for accreditation from the American Association of Museums; the application has been granted Interim Approval contingent upon the evaluation of an AAM-appointed team of museum directors who will make a site visit in the fall. It is hoped that this certification of professional legitimacy will be constructive in attracting the additional public and foundation support essential for the operation of the program.

An important infusion of long-range support was provided by announcement in November of the gift of $1 million from Vera List to establish an endowment for LVAC programs. The first of five annual $200,000 contributions was received. An Advisory Board to provide support and counsel and chaired by Ruth Bowman was established through CAMIT; its members, including three non-CAMIT contemporary art museum professionals nominated by Katy Kline, met twice to develop strategies for constructive contributions to LVAC operations and acquisitions. The group acknowledged the importance of curatorial travel in the development of exhibition projects and professional networks by awarding grants of $2500 each to the curator and director for research and professional conversations in Europe.

The LVAC applied in December to the Museum Program of the National Endowment for the Arts for support toward an exhibition titled "Corporal Politics" sculpture by Kiki Smith, Robert Gober, Annette Messager and Rona Pondick. The grant was approved by the Special Exhibitions peer panel and endorsed virtually unanimously (11-1) by the National Council on the Arts, the NEA's advisory board. The NEA Acting Chairman, however, rejected these recommendations and refused to fund the project. Her interjection of politics and content restrictions which are at odds with the NEA enabling legislation triggered strong reaction nationwide. List Visual Arts Center staff spent much of the month of May responding to overwhelming press and media attention focused on the event and its aftermath. On the positive side, contributions by the rock band Aerosmith ($10,000) and the playwright Jon Robin Baitz ($7500) as well as numerous smaller gifts provided the gratification of solidarity across various arts disciplines and nearly made up the lost funding.

EXHIBITION SCHEDULE

Ten exhibitions (in addition to the annual display of the Student Art Loan prints) were mounted in the three galleries. The roster of artists represented was international; projects ranged from single-person surveys to group exhibitions illustrating a particular theme.

Jana Sterbak: States of Being (Hayden Gallery, October 5 - November 24, 1991). A ten-year overview of the sculpture of this Czech-born, Montreal-based artist who focuses on the human body and its relation to private and public space and movement. (Organized by the National Gallery of Canada) The exhibition was cited as Best Museum Exhibition in the *Boston Globe* annual awards.

May Sun: Fugitive Landing (Reference Gallery, October 1 - November 24, 1991) A full gallery installation involving video, water and audio, based on the sometimes secret journeys of Sun Yat-Sen, the radical Chinese statesman. The artist was in residence for three weeks, the 17th in the ongoing series of LVAC based residency commissions.

Per Kirkeby: Paintings and Drawings (Hayden Gallery, December 13, 1991 - February 9, 1992) The first one-person United States museum exhibition by this well-known Danish artists whose large gestural abstractions are rooted in the dark northern European landscape tradition. Organized by the LVAC; 48-page color catalogue published. The exhibition will travel to three other museums during 1992-93.

Luis Camnitzer: A Retrospective (Reference and Bakalar Galleries. December 13. 1991 - February 9. 1992) Objects and photographs on contemporary art world and international politics by this Latin-American conceptual artist. (Organized by the Lehman College Art Gallery). A symposium, "The Marginality of the First World: Multicultural Perspectives in Contemporary Art", with moderator Benjamin Buchloh and panelists Luis Camnitzer, Homi Bhabha, Eugenio Dittborn, Charles Merewether, and Yong Soon Min was presented in conjunction with IAP.

Science Fictions: Orshi Drozdik and Jon Tower (Hayden Gallery, February 29 - April 18, 1992) Two New York-based artists who each subvert the certainties and objectivity of sciences such as Enlightenment physics, Linnean botany and genetics. Organized by the LVAC; 48-page illustrated catalogue published.

Cannibal Eyes (Reference Gallery, February 29 - April 18, 1992) Works by John Schlesinger, Aura Rosenberg, Tina Potter, Joachim Schmid and John O'Reilly, artists/photographers who re-photograph and radically re-juxtapose existing photographs into their own work. Organized by the LVAC; 24 page illustrated catalogue published.

Deborah Small: The Captivity Narratives (Bakalar Gallery, February 29 - April 18, 1992) A three-part installation based on the original new world, European narrative form. Reproductions of images and texts from accounts of the historical abductions of Mary Rowlandson and Jemima Boone were juxtaposed with the contemporary "bodice-ripper" romance. (12-page color catalogue published)

The Process of Elimination: The Bathroom, The Kitchen and The Aesthetics of Waste (Hayden Gallery, May 9 - June 28, 1992) An investigation of the overlapping patterns of biological digestion, economic consumption and aesthetic simplification in the development of these two charged domestic locations. Guest curated by design historians Abbott Miller and Ellen Lupton. Educational program: lecture "Waste Today: Does Responsible Design Mean Boring Design?" by Mierle Ukeles, noted Artist-in-Residence at the New York City Department of Sanitation. 74-page illustrated book published; co-distributed with Princeton Architectural Press.

Terra Nova: Drawings and Models by Lebbeus Woods (Reference Gallery, May 9 - June 28, 1992) Wildly visionary and inventive projects exploring alternative possibilities in societal living by this influential teacher and founder of the Studio for Experimental Architecture in New York.(Organized by the University Art Museum, California at Long Beach). LVAC produced a 14-page illustrated catalogue.

Peter Campus (Bakalar Gallery, May 9 - June 28, 1992) Master manipulations with computer of images by this well-known New York video artist and photographer, in both his customary black and white and new color work shown for the first time. Campus was Artist in Residence at CAVS and the Visual Arts Program during the spring semester, sponsored by the Associate Provost for the Arts.

ACQUISITIONS

Permanent Collection

The MIT Permanent Collection acquired 17 works of art through gift and two works by purchase. The 1% for Art commission for the Biology Building currently under construction was awarded by the Biology Building Art Committee, working with Katy Kline, to the well-known California ceramic artist James Melchert. The work will be completed with the building in 1994.

Student Loan Art Collections

The MIT Student Loan Art Collections acquired 25 works of art through gift and 14 works by purchase. (Detailed descriptions of all acquisitions are available from the LVAC.)

LOANS FROM THE PERMANENT COLLECTION

Alex Katz, *Study for Ada and Flowers* to the Munson-Williams-Proctor Institute Museum of Art, Utica for the exhibition *Alex Katz: Drawings 1946-1989*, October - November 1991 and subsequent tour to Colby College, Maine, early 1992, and the Arkansas Art Center, June - July 1992.

EXTENDED LOANS TO THE COLLECTION

As noted in previous annual reports.

CONSERVATION OF THE PERMANENT COLLECTION

Michael Mazur's monumental twin monotypes *Wakeby Day* and *Wakeby Night* were remounted and reframed in 100 Memorial Drive dormitory by The Old Cambridge Company.

John Grillo's painting *Yellow and Orange* was treated by the Center for Conservation and Technical Studies, Harvard University Art Museums.

Jasper Johns's print *Device* was treated by Krista Gaehde.

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

MISCELLANEOUS NOTES

Outside funding for exhibitions totaled $80,550 and included awards from such sources as The National Endowment for the Arts, the Graham Foundation, The Royal Danish Embassy, The Canadian Consulate General and The Goethe Institute.

The LVAC received the *Boston Globe* Best of Boston award for **Best Public Art.**
Curator Helaine Posner, serving on the Cambridge Public Art Commission, was cited by Cambridge Mayor Kenneth Reeves and the Cambridge City Council for "her commitment to the advancement of art and artists". She also served on the Visual Artists Selection Committee for Bunting Fellowships at Radcliffe College as well as other panels and juries.

Katy Kline received a grant from the Asian Cultural Council and traveled to Tokyo, Kyoto and Yokohama to investigate the situation of the woman artist in Japan. She also served on the Lowell Public Art Commission and the New England Holocaust Memorial Competition jury as well as numerous other panels and juries.

Special tours were arranged for classes from area schools and colleges, as well as for out of town visitors such as the trustees of the Williams College Museum of Art and the Members' Council of the Center for Fine Arts, Miami.

List Visual Arts Center Staff

MIT Museum

In FY92 the MIT Museum celebrated many of the Institute's greatest treasures. Exhibitions featured the work of graphic designer Jacqueline Casey, Department of Architecture founder William Robert Ware, and Nobel physicist Henry Kendall. Our educational program *So You Think Math and Science Are Boring* introduced 10-16 year-old students to the laboratories and research centers of MIT, while walking tours guided Museum patrons on expeditions to notable buildings designed by MIT Department of Architecture faculty and alumni. A state-of-the-art multimedia museum catalogue project was launched, the initial phase of which will focus on the life and work of Harold "Doc" Edgerton.

The Museum also paid tribute to institutions and traditions beyond the MIT campus with exhibitions on Buckminster Fuller and the art of the microchip, with a nautical lecture series which explored the history of marine navigation, and with the first annual Ig Nobel Prize ceremony, a good-natured, high-spirited lampoon of the Nobel Prize which caught the attention of the national and international press. But these were just a few of the highlights of a rewarding year.

COLLECTIONS

A corporate foundation grant for $50,000 enabled us to commence planning for the computerization of the Museum's collections, and to make the resulting catalogue available to the Institute and beyond via MITnet. This project is being undertaken in collaboration with the Center for Educational Computing Initiatives (CECI), whose research on multimedia applications design will enable the Museum to present its collections in particularly innovative and exciting ways. Consisting of photographs, moving pictures, equipment, and memorabilia, the Harold "Doc" Edgerton Collection will be the first to be computerized.

The Museum is now in the planning stages of a project to create, in collaboration with CECI, a multimedia archive which tells the story of MIT's history, research efforts, and current activities. The Edgerton application will be the first in a series to highlight the MIT personalities who have contributed so much to the life of the Institute.

The Collections staff was busy loaning and accessioning artifacts, and performing research for clients inside and outside MIT. FY92 accessions included materials from MIT notables Edward Bowles, Jackie Casey, Samuel Collins, and Jerrold Zacharias; instruments were donated by departments such as the Man-Vehicle Lab, Department of Electrical Engineering and Computer Science, Research Lab of Electronics, and Draper Lab. Among the many clients who used the collections for research or who were loaned artifacts this year were WGBH, WHDH, ESPN, the National Portrait Gallery, the Museum of Our National Heritage, the Boston Museum of Science, national and international researchers, and professional societies such as the American Institute of Physics, the American Society for Engineering Education, and the Association for Computing Machinery. Materials from the collections were featured in several of the Museum's exhibits this year including MIT/Casey, **Drawings at Work: William Robert Ware and the Origins of American Architectural Education**, and **A Thousand Years of Voyages of Discovery**.

Supported by funding from Ruth Baker and an Institute of Museum Services Conservation Program grant, the William A. Baker Collection was catalogued and rehoused in FY92. William Baker was the curator of the Hart Nautical Collection from 1963-1980, and the Baker Collection includes his ship designs and numerous publications.

Two humungous late-eighteenth-century Continental mural paintings were restored for McCormick House after a two-year conservation effort. A rare 19th-century French architectural drawing by Emmanuel Brune was conserved and restored for the **William Robert Ware** exhibition with funding from the Council for the Arts at MIT.

EDUCATION

K-12 Our K-12 educational programs brought more than 100 school groups to the Museum this year. Children enjoyed participating in our two regular programs, *Seeing and Touching Geometry*, in which they explored geometry utilizing hands-on math manipulatives and "seeing" exercises, and *Flash!*, which introduced students to the artistic and scientific legacy of Doc Edgerton, allowing them to participate in "seeing the unseen." The

Museum's education coordinator continued to serve as a liaison between the Cambridge school system and the laboratories of MIT. This informal role was expanded into a spring vacation week program, *So You Think Math and Science are Boring*, which featured visits to the Media Lab, where children watched a hologram being made, the Strobe Lab, where they made and starred in their own strobe photographs, a stop at the Mechanical Engineering Lab, where MIT students were testing their designs for the 2.70 contest, a trip to a research vessel in Boston harbor where students took a core sample, the Artificial Intelligence Lab, where children were introduced to the concepts and machinery of AI, and a tour of the nuclear reactor. The enthusiasm generated by this program in schoolchildren and MIT researchers alike has led to plans to expand the program in FY93, working in collaboration with the Cambridge school system's Science Coordinator. This program was funded by a grant from a local foundation.

MathSpace, our hands-on math discovery room, successfully completed its first full year. MIT students guided visitors through **MathSpace**, helping them create their own polyhedral sculptures, kaleidoscopes, and other geometric constructions. We are in the process of expanding this very popular facility by renovating a larger adjoining space, which will allow us to create a classroom incorporating more activities which complement our exhibit of geometric sculptures, **Math in 3D.**

Funding was provided by the Council for the Arts at MIT for publication of a workbook used in conjunction with the Fall '91 Buckminster Fuller exhibit. The workbook was introduced in teacher workshops to encourage the teaching of geometry using hands-on methodology. The Museum also hosted meetings of the Boston-area Museum Educators Roundtable and the Cambridge Science Advisory Education Council.

Adult Education *Marine Navigation from Micronesia to MIT*, an exceedingly popular lecture series organized by the curator of the Museum's Hart Nautical Collections, traced the development of navigation from prehistoric methods to the latest developments in marine and submarine technology. We also presented a host of programs in conjunction with the exhibition *Drawings at Work: William Robert Ware and the Origins of American Architectural Education*, including a gallery talk, lecture by Ware scholar J. A. Chewning, and walking tours of the Back Bay and Cambridge which illustrated the influence of MIT Architecture professors and graduates on the local urban landscape.

EXHIBITS

Henry W. Kendall: Arctic and Expeditionary Photographs May 6 - August 30, 1992. A photographic exhibition of dramatic mountainscapes from Yosemite to the Himalayas, from the Peruvian Andes to Baffin Island in Canada's eastern Arctic taken by physicist Kendall from 1957-1990. The exhibition was mounted in conjunction with the 46th Anniversary Celebration and Symposium of the Laboratory for Nuclear Science at MIT.

MIT/Casey April 25 - September 18, 1992. A thirty-year retrospective of the work of graphic designer Jacqueline S. Casey, who played a pivotal role in putting MIT on the visual arts map. Her successful integration of visual and verbal language illustrates the point that effective communication is a defining quality of civilization. The catalogue *Posters - Jacqueline S. Casey - Thirty years of design at MIT* was published in connection with the exhibition.

Drawings at Work: William R. Ware and the Origins of Architectural Education April 24 - September 25, 1992. This critically-acclaimed exhibition featured drawings from the Museum's Architectural Drawings Collection, including a selection of rare drawings by 19th-century English and French architects collected by William Robert Ware, who founded MIT's Department of Architecture in 1868. Drawings from this collection, recently rediscovered, were on display for the first time since World War II. Plans and elevations executed by Ware as a practicing architect and early student drawings illuminate the approach used to teach architecture at MIT, the first institution in this country to offer a formal program in architectural education. This exhibit was supported by funding from the Council for the Arts at MIT, the Department of Architecture, and the Martin E. Zimmerman '59 Fund.

Thinking the City: Twelve Views from MIT February 18 - August, 1992. Twelve design faculty members of MIT's Department of Architecture, working with students, formulated an installation which explored new attitudes about the city. Each produced an original exhibit, some focusing on urban design in general, others on specific aspects of the Boston cityscape. An aluminum grid of Boston streets was suspended from the ceiling to create a point of reference for the individual exhibits below. Support from the Office of the Provost and the Council for the Arts at MIT helped fund the exhibition.

Douglas Brown February 28 - April 26, 1992. Colorful, convention-defying watercolors by MIT chemical engineering alumnus Brown '21, who ultimately devoted his career to art, rather than engineering. The Council for the Arts at MIT funded an accompanying gallery brochure.
Information Art: Diagramming Microchips February 11 - April 5, 1992. Organized by New York's Museum of Modern Art and made possible by the Intel Corporation, the exhibition featured thirty-one computer chip plots. The complex patterns of these circuits resembled the weave of oriental textiles, aerial views of cities, and sumptuous abstract paintings.
No Apartheid Anywhere: Works by Valerie Maynard January 17 - March 20, 1992. In creating this ongoing series, Maynard, a printmaker, sculptor, and painter, works with black acrylic spray-painted over a collage of found objects to create striking human images. A significant relationship between superficially unlike objects is part of the Maine-based artist's statement about apartheid -- that difference should not necessarily imply disharmony. Selected as an artist-in-residence at MIT, Maynard also taught a sculpture class during IAP in conjunction with the show. The Council for the Arts at MIT funded a brochure which accompanied this exhibit.
Architectural Illusions: Sculptures by Raymond Bareiss October 10th - December 27, 1991. Revolving 6'- 9' columns demonstrated structural anomalies and optical illusions discovered by this west coast artist.
Buckminster Fuller: Harmonizing Nature, Humanity and Technology September 20 - December 15, 1991. A retrospective organized by Bard College on the work of the late visionary scientist, philospher and Renaissance man (who taught for several years at MIT) included geometric constructions, models and drawings of experimental furniture, cars, and other inventions, and photographs and natural forms from Fuller's personal memorabilia. The Council for the Arts at MIT funded an accompanying workbook for teachers.
A Thousand Years of Voyages of Discovery Sept. 3, 1991 - ongoing. This exhibition, mounted in collaboration with the Department of Ocean Engineering and MIT Sea Grant Program, was created at the suggestion of MIT alumnus Knut Kloster '51. Kloster organized the *Vinland Revisited Project*; three Viking-era ships were reconstructed and sailed along the route earlier sailors may have taken when exploring North America. The exhibit highlighted historic explorations of the sea including early Polynesian migration, the Viking's westward voyages, Captain Cook's legendary Pacific explorations, and man's current efforts to understand the oceans' depths. This exhibit was funded by the Department of Ocean Engineering.
Made of Light: Photographs by Barry Perlus July 2 - Sept. 8, 1991. Cibachrome prints of the architecture and sculpture of Mamallapuram and Ellora, as well as a visual essay of Jantar Mantar, the celebrated observatory in New Delhi, were featured.

Special Exhibitions
Once again the Museum mounted the annual children's art exhibit for the Medical Department. Framing was also done for the Department of Ocean Engineering.

For the second year, the Museum organized a student photography contest in conjunction with the MIT Alumni/ae Association commemorating the work of Doc Edgerton and Gjon Mili. The winning photographs are on display at Strobe Alley, and a very popular calendar was produced by the Alumni/ae Association using images from the 1991 contest.

Earth, Sea, and Sky, the major exhibition of works by Charles H. Woodbury and **Seeing the Unseen: Photographs by Harold Edgerton** continued on their national tours. **Postcards from Ogunquit**, an exhibition of sixty pochades by Charles H. Woodbury, was loaned to the Christian Science Center, Boston, the Lynn Historical Society, the Midwest Museum of American Art in Elkhart, Indiana, and the Ogunquit Art Association, Maine.

FACILITIES
The Museum hosted 66 receptions and dinners for nearly 3,000 guests, including a reception for the 45th Anniversary of the Research Lab of Electronics, a dinner meeting for the Mayor's Institute on City Design, a symposium for the Department of Architecture which was held in conjunction with the Boston meeting of the American Institute of Architects, the 100th anniversary celebration of Delta Upsilon, and a reception for the Council on Governmental Relations.

MUSEUM SHOP
The MIT Museum Shop, with two stores and a full-color mail order catalogue, exceeded the one-half million dollar mark in sales in FY92. In conjunction with the MIT Museum's MathSpace facility, the Shop has initiated an educational kit rental program to provide local educators with the materials needed to duplicate or expand

upon the concepts introduced in MathSpace. This program enables schools, which could otherwise not afford the purchase of kits and models, with the opportunity to rent them at reasonable cost. The Museum Shop has also developed an exclusive line of high-quality MIT memorabilia designed specifically for Institute gift-giving. The response of our clients, particularly the various MIT Alumni Clubs throughout the world, has encouraged us to expand this product line.

IG NOBEL

A generous contribution from the Peter De Florez Fund for Humor at MIT was instrumental in making the Ig Nobel Prize an overnight tradition with an international following. In partnership with the *Journal of Irreproducible Results*, the MIT Museum sponsored this spoof of the Nobel Prize which featured an all-star cast of Nobel laureates who presented screaming medallions to a notorious collection of recipients amidst much pomp and silliness. News articles still surface in the national and international press about the 1991 ceremony, and news organizations are already making arrangements for coverage of the October 1992 festivities. A spate of letters to the editor of *Scientific American* continue to debate whether the Ig Nobel is an instance of big science bashing little science.

ADMINISTRATIVE

Major grants received during FY92 included those for the collections computerization project, a 1992 Institute of Museum Services (IMS) Conservation grant (which matched an earlier gift from Ruth Baker) used to catalogue and rehouse the Hart Nautical William Baker collection, and a 1992-3 IMS General Operating Support grant ($75,000) which will be used to support basic museum services during FY93, with a focus on enhancing and expanding our educational programs. Smaller grants, both in-kind and cash, funded the Spring Vacation educational program, supported the Museum Shop, and made possible research on the Architectural Drawings Collection.

The director taught a Freshman Advisor Seminar on Institute history for the fourth year, and presented his ever-popular lecture on MIT traditions to incoming students, graduating seniors and their families, family weekend, and alumni groups.

The MIT Museum Staff

Council for the Arts

The Council for the Arts, under the leadership of John W. Kunstadter '49 (Chairman) and Martin N. Rosen '62 (Vice Chairman), continued to fulfill successfully its mandate to foster the visual, literary, and performing arts at MIT by coordinating its programs with Institute objectives and priorities as advisors to Ellen T. Harris, Associate Provost for the Arts. The year was distinguished by the establishment of two new standing committees, an unprecedented number of new Council membership appointments, continued demand for Grants Program funding, and a significant increase in nominations for the Council's endowed prizes and awards. The Council's Executive Committee, six standing committees and three prize committees conducted regular meetings throughout the year to discuss and discharge their particular responsibilities.

COUNCIL STANDING COMMITTEES

Annual Meeting (Catherine N. Stratton, Chair)

The Nineteenth Annual Meeting of the Council for the Arts at MIT was held on November 14-15. Seventy-three Council members and guests attended the meeting.

Among the activities organized for the Annual Meeting was an interdisciplinary panel on "Arts Advocacy and Education" featuring four younger members of the MIT faculty who are themselves creative artists. Participating as panelists were Decima Francis (guest instructor, Theater Arts), Elizabeth Goldring (instructor, Center for Advanced Visual Studies), Stephen Tapscott (Professor, Literature; co-recipient of the Council's 1991 Kepes Prize Fellowship) and Evan Ziporyn (Assistant Professor, Music).

Two directors of the Office of the Arts apprised Council members of new activities under their respective purview: Maureen Costello, Director of Special Programs, described objectives and initiatives of the Artists-in-Residence Program, and Mary Haller, Director of Arts Communication, reported on publications and public relations efforts on behalf of the arts at MIT. Professor Ellen T. Harris, Associate Provost for the Arts, delivered her comprehensive "State of the Arts" address, summarizing both the achievements and aspirations of a dynamic arts environment throughout the MIT curriculum and community.

Development (Martin N. Rosen '62, Chair *ad hoc*)

Fundraising was perhaps the one area of Council operations that did not enjoy robust success this year. Like many other arts advocacy and cultural organizations, the Council experienced a downturn in individual giving. Generous contributions from Council members and friends and prudent management, however, resulted in a budget surplus for the fifth consecutive year. Forty members provided unrestricted contributions averaging $4,103. Twenty-two non-member donors contributed an average of $1,039 each. Designated contributions totalling $283,209 were made by nine Council members to specific MIT arts programs. That substantial sum includes the first gift of a five-year, $1 million pledge by Vera List to establish an endowment for the List Visual Arts Center.

Grants Program (Bradford M. Endicott '49, Chair)

The Grants Committee considered 62 applications for arts project funding from students, student groups, staff, and faculty requesting a total of $121,770. Funding was recommended for 45 projects, with grants totalling $57,350. Ten Officer's Grant proposals were reviewed by the Council Director and awarded a total of $1,965. A detailed report of Grants Program activity is available.

Among the notable projects awarded Council grants this year were those to the MIT Concert Choir and Chamber Chorus for its presentation of J.S. Bach's *St. Matthew Passion*, featuring one hundred-fifty student vocalists and instrumentalists; Paul Earls, Fellow at the Center for Advanced Visual Studies, in support of the world premiere of *Mozart and Cosmology*, a multi-media production inspired by the music of Mozart and cosmological theory, created by Mr. Earls and Beth Soll, director of MIT's Dance Workshop; the Women's Studies Program and the Film and Media Studies Program to present "Black Women Filmmakers: Vision and

Image," a series of screenings and discussions with three pioneering filmmakers; and Lerothodi Leeuw '92 for his exhibition of photographs and poems of South Africa, entitled "A Moment for Milk," displayed at the Wiesner Student Art Gallery.

List Visual Arts Center Advisory Committee (Ruth Bowman, Chair)
The List Visual Arts Center Advisory Committee has been established to assist the List Center staff in developing and recommending exhibition and collection policies and education programs. The committee is composed of ten Council members with interest in contemporary art and three museum professionals from other institutions: Richard Andrews, director of the Henry Art Gallery in Seattle; Gary Garrels, senior curator at the Walker Arts Center in Minneapolis; and Andrea Miller-Keller, curator of contemporary art at the Wadsworth Atheneum in Hartford.

In its first year of operation, the committee approved funding for curatorial travel to *Documenta* '92, a prestigious international exhibition held every five years in Kassel, Germany; and for acquisitions of work to the MIT Permanent Collection and Student Loan Collections.

Membership (Bernard G. Palitz '47, Chair)
At the conclusion of the academic year, Council membership stands at 75, excluding five *ex officio* members and two Life members. Sixteen of the 18 members whose terms expired at the end of June were invited to renew their participation.

Thirteen individuals accepted appointments to the Council from President Charles M. Vest: Marion Alden, Richard J. Bertman '60, Kitty and Herbert Glantz '52, Ellen R. Greenberg '68, Freddy Homburger, Dorothy and Leroy Lavine, David B. Liroff '65, John D. Proctor '73, Joan and Robert Rudy '37, and Stuart Z. Uram '56.

Gregory Smith '30, a founding member of the Council and long-time chairman of the Development Committee and member of the Executive Committee, was honored as the second Life Member of the Council for the Arts at the Nineteenth Annual Meeting in November.

Howard W. Johnson, Institute President Emeritus and Council member since 1986, resigned in December. William F. Blitzer '45 and John Karmazin, Jr. '47, Council members respectively since 1980 and 1985, declined to renew their appointments.

We regret to note that Haskell R. Gordon '38, who was appointed to the Council in 1986, passed away in September.

MIT Museum Advisory Board (Ronald A. Kurtz '54, Chair)
The MIT Museum Advisory Board has been established to assist the Museum staff in developing and evaluating exhibition and education programs, planning and fundraising priorities, and conservation and collection policies. Subcommittes have been formed to support activities in each of these mission areas. The diverse Advisory Board is composed of nine Council members, four current or former MIT faculty, and four unaffiliated MIT alumni.

In its first year of service, the board approved allocations to support five exhibitions scheduled in the 1991-92 season: "No Apartheid Anywhere: Works by Valerie Maynard"; "Color/Form: The Geometric Sculptures of Morton C. Bradley, Jr." (also known as "Math in 3-D"); "Watercolors by Douglas E. Brown '21"; "Drawings at Work: William R. Ware and the Origins of American Architectural Education"; and "MIT/Casey."

SPECIAL PROGRAMS

Endowed Prizes and Awards
The Gyorgy Kepes Fellowship Prize was presented by Angus N. MacDonald '46 (Kepes Prize Committee

Chair) to Beth Soll, director of the MIT Dance Workshop, at the Council's Nineteenth Annual Meeting in November. The Kepes Prize citation praised Ms. Soll's choreography for "combining emotional strength with delicacy...immers[ing] us in magic, music, myth and science, invoking a myriad of references to impel and illuminate her art."

Three representatives from the Boston arts community assisted the Kepes Prize Committee in its deliberations this year: Rebecca Blunk, Director of Performing Arts at the New England Foundation for the Arts; Gail Caldwell, senior literary editor of *The Boston Globe*; and Matthew Teitelbaum, curator at the Institute of Contemporary Art.

The Eugene McDermott Award was presented by Ida Ely Rubin (McDermott Award Committee Chair) to Rebecca Purdum, an abstract painter from New York, at the Council's Nineteenth Annual Meeting in November. With the bestowal of the McDermott Award, Ms. Purdum was commended as "an artist whose intelligence, humanity and conviction capture the lyrical landscape of emotion."

At the Institute Awards Convocation in May, the Laya and Jerome B. Wiesner Student Art Awards were presented by Ellen T. Harris, Associate Provost for the Arts, to Jill B. Soley '92 (Architecture) for production of video documentaries that "illuminate human relationships with candor and compassion"; Tarik K. Alkasab '92 (Physics with Electrical Engineering) for his leadership of the Musical Theater Guild; and Uri Wilensky, graduate student (Media Arts and Sciences) for his founding and organization of the successful "Poetry at the Media Lab" reading series. Professor Harris also presented the Louis Sudler Prize in the Arts to Alexander P. Rigopoulos '92 (Humanities) for excellence in music composition.

The second annual "Playwrights in Performance" series of student-written one-act plays was presented in May. These four plays were selected from the playwrighting workshop directed by Alan Brody, Head of the Theater Arts section. The program is fully supported by the Richard P. Rudy '68 Memorial Fund established by Joan and Robert Rudy '37.

Museum Membership Programs
The Boston Museum of Fine Arts University Membership Program provides free admission and discount benefits to all MIT students. Ten museum membership cards are also distributed for the daily use of MIT staff members. Enrollment in this program has been made possible through Council support since 1980.

The Council also underwrites MIT's institutional membership at the Institute of Contemporary Art in Boston. All MIT students receive a discount admission fee to exhibitions, films and special programs at the ICA.

***Invention for Fathers and Sons* Event**
To celebrate the New York production of *Invention for Fathers and Sons*, a play by Alan Brody, Professor of Theater and chair of the Music and Theater Arts Section, a special theater evening for the Council was organized in January. Thirty-nine Council members and guests attended the performance at the American Jewish Theater and dinner at a nearby restaurant with Professor Brody and the play's cast.

Wasserman Forum on Contemporary Art
The second annual Max Wasserman Forum on Contemporary Art, "Seeing is Believing: History, Art and Interpretation" was presented in May at the Wiesner Building. The forum examined the often controversial relation of historical event, artistic representation, critical interpretation and public opinion by considering recent cultural case studies: the exhibitions "The West as America" at the Smithsonian Institution and "Places with a Past" at the 1991 Spoleto Festival USA; the opera, *The Death of Klinghoffer*, at the Brooklyn Academy of Music; and the film, *JFK*. Michael Kammen, Farr Professor of American History and Culture at Cornell University, delivered the keynote address. Panel respondents were William Truettner, curator at the National Museum of American Art; Mary Jane Jacob, an independent curator of contemporary art; and J. Hoberman, senior film critic for the *Village Voice*. The program was developed by Mark Palmgren, Director of the Council for the Arts, who served as moderator.

MARK PALMGREN

DEAN FOR UNDERGRADUATE EDUCATION AND STUDENT AFFAIRS

INTRODUCTION

In the 1991-92 Report to the President, I described the year which had just ended as one of transition—there had been many changes in the leadership of the Office of the Dean for Student Affairs and in the leadership of the Institute. New directions were being developed and priorities were being reviewed and changed. I looked forward to the current year as one in which the transition would have been largely complete and we would be progressing along our new paths.

Instead it has been another year of transition; in February, the decision was made to combine the Office of the Dean for Undergraduate Education with the Office of the Dean for Student Affairs. This change gives us the opportunity to coordinate efforts and bring new vitality to a number of programs that support the educational activities of the faculty. At the same time, we expect to be able to be more effective in providing services to all our students.

The new name of the combined office is Undergraduate Education and Student Affairs (UESA). It is our hope that by removing the separation between the offices which dealt with educational activities and with the other aspects of student life, we can offer programs and services which deal more effectively with the entire student experience. Some duplications will be removed and synergistic programs will be strengthened.

It is important to note that as this major reorganization was proceeding the programs and services which we have provided in the past continued at a high level. In the reports that follow, you will see evidence of the professional competence of the staff of Undergraduate Education and Student Affairs and a description of the innovative activities they envisioned and carried out. This is an outstanding staff, capable and committed, who work without regard to time spent or nominal job descriptions. The Institute is fortunate to have them and I am proud to be associated with them.

Once again, I am looking forward to a new year in which our directions have been determined, our priorities have been set and our progress can accelerate. Perhaps this year I will be right.

ARTHUR C. SMITH

CENTRAL ADMINISTRATION

The Central Section provides administrative services and facilities support to Undergraduate Education and Student Affairs. Several major improvements have been made in the office facilities in Buildings 5 and 7 during the year and the establishment of an effective computer network continues. The section provides staff support to the Committee on Discipline and the Committee on Student Affairs. The Public Service Center is also included in the section and its expanded activities are reported below.

Affirmative Action Successes and Objectives

UESA continued to maintain a strong commitment to Affirmative Action during the year with a staff that was 20 percent minority and 33 percent male. The following table reflects the race/ethnicity and gender profile, as of June 30, 1992 of the 54 full- and part-time staff within UESA.

	Minorities	Non-Minorities	Total
Administrative & Academic Staff			
Male	4	12	16
Female	4	17	21
Subtotal	8	29	37
Support Staff			
Male	1	1	2
Female	2	13	15
Subtotal	3	14	17
TOTAL	11	43	54

The 37 administrative staff included 6 Black employees (3 men and 3 women), a Mexican male and a Native American female. Of the 3 minority staff among the 17 support staff, there was 1 Puerto Rican male and two females, 1 Asian and 1 Asian American.

For Fiscal Year 1993, UESA has successfully met its objective of securing an Asian presence on the administrative staff. An Asian American female will join the department in August as an Assistant Dean.

Public Service Center

The MIT Public Service Center (PSC) has finished its third complete academic year. It has been an active and successful year which has seen the continuance of earlier projects and the start of several new activities. Major projects of the year include Outreach, Public Service Day, Giving Tree, Fellowships, and City Days.

An effort was made, starting last summer, to reach out to the MIT community and make public service an easier option. This was done in several different ways. Public service interest cards were sent to all incoming freshmen in June, 1991. 394 students returned these cards to PSC in July, and their names were given to the appropriate student activity groups on campus, who then contacted the freshmen directly. Outreach: *A Resource Guide for Volunteering in Cambridge and the Greater Boston Area,* was designed in August, with a listing of over 100 local agencies. 2000 copies of this booklet were sent to the Office of Special Community Services, undergraduates, interested graduate students (from spring survey), housemasters, graduate residents, and community service chairs and presidents of dorms and independent living groups (ILG's). PSC also had a booth at the Activities Midway, which gave 'first years' another chance to express their interest in public service. The semesterly PSC newsletter, *Outreach,* acknowledged student public service efforts and listed upcoming projects. Volunteer opportunities were again published in the campus newspapers. A 'pizza' meeting was held in March for living group service chairs; we presented them with different, interesting ways of organizing service days and a list of current, accessible, and fun spring projects.

The second *Public Service Day* was on October 5, 1991. 363 students worked for 3.5 hours each at 35 different agencies. The agencies were divided into five categories: Education, Health and Medical, Homelessness, Hunger, and Underprivileged Youth. Students were assigned to a specific project at an agency with their group. The day drew students from a large number of MIT living groups and student activity groups and gave them an opportunity to work in the community of which they are a part.

In December the PSC again sponsored the third annual *Giving Tree* Program, which provided presents to underprivileged children in the Boston/Cambridge area. Thirty-four campus organizations (living groups, student activity groups, and MIT offices) participated, providing 1442 presents. These were distributed through eleven different agencies. The *Tech Talk* published a note thanking the MIT community for contributing to the *Giving Tree*. The Director of Social Service at the Elizabeth Peabody House wrote a letter to the editor of *The Tech* entitled, "MIT students understand the meaning of Christmas".

The PSC publicized, coordinated, and awarded the *MIT Public Service Center '92 Fellowships.* The $1200 Fellowships, funded by the Lord Foundation and the MIT Employee's Federal Credit Union, were awards for intensive public service work. Each project, done in conjunction with a Cambridge/Boston organization, is a substantial effort in the interest of serving community and local needs. In December '91, thirteen IAP and seven Spring '92 Fellowships were awarded. In May '92 another seven fellowships were announced, for Fall '92. Of the 27 Fellowship winners, 13 were male and 14 were female. There were seven fellows from the Class of '92, seven from the Class of '93, six from the Class of '94, and seven from the Class of '95. The fellows were honored at Priscilla Gray's (co-chair of the PSC Steering Committee) in December and May. We have received another $30,000 from the Lord Foundation for 1992-93.

"Politics, Cambridge, and the MIT Student", a Political Science 12-unit seminar with Undergraduate Academic Affairs (UAA) and PSC support, was offered for the second year. Matching student interests, six to eight hours are spent weekly working with a Cambridge agency. The Political Science Department, originally pledging to offer this seminar for two years, will now offer it every spring.

In February, the PSC Steering Committee decided that freshmen should be specifically "targeted". Because Labor Day falls late this year and MIT has two extra days before registration, the idea of *City Days: A Two-Way Street,* a new event during R/O '92, emerged; it is designed to give MIT students a better understanding of their new urban community. The aim is to allow MIT students and Cambridge intermediate grade students to learn and have fun together, during *City Days* and with academic-year follow-through in two ways: after-school sports programs cut by Proposition 2.5 and science fairs and clubs and a possible city-wide competition. A planning committee (including the UAA and the Office of Government and Community Affairs) was formed and has been meeting weekly. The semester was spent contacting MIT student groups, the Cambridge School Department, and principals, science specialists, and parental liaisons of the schools. MIT students made presentations and distributed flyers to third-fifth grades at each of the thirteen elementary schools. Flyers,

with attached permission slip, were then translated into six languages and sent to the parents. Monday, September 7, is being billed as 'MIT Goes to the City': there will be tours and service projects during the day, speeches and entertainment in the evening. On Tuesday ('The City Comes to MIT') 650 fourth-sixth grades will spend the day with members of 42 (out of 48) living groups, eating and enjoying activities sponsored by those living groups and 20 labs, centers, departments.

MARILYN L. BODNAR
STEVEN M. BURKE
VIRGINIA M. SORENSON
BETTY H. SULTAN

OFFICE OF MINORITY EDUCATION

The Office of Minority Education (OME) gave particular significance to the 1991/92 year through the establishment of OME's super ordinate goal: "To become recognized as an agent of positive change and innovation in education at MIT." Through an intense self-study, thorough assessment and thoughtful strategic planning for the next five years, the OME staff completed a series of professionally-led team-building sessions. These sessions resulted in reaffirmation of OME's commitment to "total quality service" in the delivery of all programs implemented through the office. This commitment to total quality has demanded that the greatest possible effort be made to identify and meet the various needs of a very diverse undergraduate student population. It also has necessitated projections that would insure the continued effectiveness of OME programs into the future.

OME's quest for excellence is evidenced in the major highlights of the year's accomplishments, as outlined below.

Project Interphase (PI) '91 enrolled 56 prefreshman minority students from 17 states and Puerto Rico, with females comprising 39%. They successfully completed a full academic and general educational program, including site visits to the Digital and Raytheon corporations, as well as the annual outing to Martha's Vineyard. In addition to the standard physics, math, and writing classes, chemistry was returned to the PI curriculum, along with a formal study skills component. As a result of the assessment conducted at the end of the program, 23 of the 56 participants (41%) tested out of 18.01 for the fall '91 semester, compared to approximately 35% in the previous year.

Program XL, the effective small-group learning seminar, sustained successful enrollment in its third year with a total of 31 groups, nearly doubling that of last year: 16 in math, 13 in physics, and 2 in freshman engineering subjects. The math and physics groupings reflected the particular classes in which the students were enrolled. An end-of-year ruling by the faculty Committee on Academic Performance promises to result in a major increase in XL enrollment for fall 1992.

Tutorial Services, formerly known as the BSU Tutorial Program, experienced a tremendous increase in usage. With a diverse workforce of more than 60 tutors (55 of whom were graduate students), OME was able to respond to virtually every request for tutoring. From the previous year, there was a 45% increase in the number of individuals utilizing tutorial services. By spring semester, the actual usage hours in the Tutorial Services Room (TSR) had increased to 606: 420 hours were spent in tutoring, 50 on the TSR Athena terminals, and 136 hours in untutored studying by students at every level. The clientele in the TSR included a good representation of both minority and non-minority students.

The Second Summer Program (SSP) was returned to the OME for administration after having been coordinated for several years out of the School of Engineering. A record 54 freshmen (11 of whom were non-minority) enrolled in the SSP workshop during the Independent Activities Period (IAP), earning six credits for the mini-course in engineering design. In collaboration with officials from the Massachusetts Bay Transit Authority (MBTA), the ten student groups developed ideas for improved wheelchair restraints for use on mass transit buses. The project resulted in the determination by the MBTA's chief mechanical officer that two of the ideas could be considered for actual implementation.

Of the 43 minority students in the SSP, 26 were selected for placement in summer internships as paid engineering aides at 15 sites in 11 Fortune 500 companies, all of which were members of the OME Industrial Advisory Council for Minority Education (see below). With the assistance of six members of the MIT faculty, each SSP student was visited on site, and it was determined that the students assumed considerable responsibility and faced the challenges of very substantive technical assignments.

New Initiatives and Major Activities

The OME Industrial Advisory Council for Minority Education (IACME) grew to 24 member companies. Each corporation sent up to three representatives to meetings during the academic year, to serve in an advisory capacity to the OME for programs implementation and new initiatives. Their presence made possible the renovation of the TSR into

a state-of-the-art tutoring facility, including work stations, a database processing unit, and development of a TSR resource library. Terrific ideas for other new initiatives were placed on the drawing board.

An exciting new Mentor Program was launched through the IACME. More than 40 scientists and engineers from among the member companies volunteered to serve as mentors and were paired one-on-one with MIT freshmen and sophomores. Several of these relationships have developed the promise of long-lasting friendships.

In addition to the traditional assistance given to the minority student organizations, several student-mounted special events received both financial and administrative support from the OME, coordinated primarily by the professional student organizations. These included regional conferences, professional seminars, and educationally focused presentations.

Staff Development and Student Enrollment

A national search to fill the OME assistant director's position yielded more than 85 applicants from 23 states. The successful candidate began his responsibilities in late August, just after a local search resulted in the hiring of an OME senior office assistant. The office, now fully staffed, formed an effective team to serve a minority undergraduate population of about 575 students. Increased use of OME services by both minority and non-minority students guarantees to put its team-building efforts to the test. Enrollment as of fall 1992 was as follows:

Total Undergraduates All Groups: 4,389	African American	Native American	Mexican American	Puerto Rican	Totals
Group Total	290	23	190	85	578
% Min. Enroll.	50	4	32	14	100
% Total Enroll.	6.6	0.5	4.3	2.0	13.4

JUDY JACKSON
RUBÉN MORFÍN-RAMÍREZ
GAIL-LENORA STATON

RESIDENCE AND CAMPUS ACTIVITIES

The Residence and Campus Activities (RCA) section of UESA has responsibility for most aspects of the undergraduate dormitory system, the residents, Housemasters and Graduate Residents, house assignments, and student governance; graduate student government and some residential concerns; Fraternities, Sororities, and Independent Living Groups; the Undergraduate Association student government; student activities and organizations; and discipline functions related to these areas. In addition, the section oversees some special programs, including the House Fellows Program and Talbot House. The year's activity in each of the major RCA activities is summarized below.

Project Awareness

This year, with the MIT Campus Police, the UESA established Project Awareness, a student liaison group dedicated to raising awareness of personal safety and crime prevention among students. In addition to holding study breaks and small discussions in the dormitories, Project Awareness students planned and staffed two Safety Days in the spring. The themes of the program—held outside the Student Center—ranged from bicycle and motor vehicle safety to a Whistle Stop program and tips on protecting your belongings from theft. More events are planned for R/O Week and the fall.

Mediation

This year RCA sponsored a mediation training program at MIT. During the academic year two training programs were instituted resulting in 37 students, staff and faculty being trained in mediation techniques. Of the 37, 21 completed the 30 hour state course allowing them to be certified as mediators by the Commonwealth of Massachusetts. Several of the 21 have continued training programs with court and city agencies.

A number of cases have already been referred to members of the mediation group. It is our hope that through continued efforts next year we will be able to expand the training program and the number of cases directed to this group.

Publications

RCA added a pamphlet on sexual identity and homophobia to its series on harassment, racism, and other student life issues. The Undergraduate Residence Book was also revamped for the first time since the 1960's. The current book—

renamed Undergraduate Residence Life—includes a wider range of student input and perspective in new sections organized thematically around various aspects of student life. The book was changed to make it more useful and appealing to freshmen considering their residential options. We are also in the process of developing a "Student Guide to Information and Services" that includes information about commonly-asked questions, rules, and procedures relating to a variety of offices and services at MIT.

TIPS Training

Three RCA staff were certified by Health Communications, Inc. to teach its TIPS (Training for Intervention Procedures by Servers of Alcohol) program on alcohol management and liability. During the last months of the academic year, several dozen undergraduates in both the dormitories and fraternities were trained and certified at no charge in successful serving and intervention techniques.

Undergraduate Housing

With the introduction of a new computer-based algorithm for freshman assignments, we drastically cut the number of students assigned to low-choice dormitories and achieved a 95% placement rate in top-three houses. We are continuing to work on refining the method and hope to be even more successful in placing the Class of 1996.

Fall 1991 was also the first year that crowded rooms were pre-designated based on the number of students in the undergraduate system. Using this "crowd grid" helped to lessen some of the confusion and uncertainty of rooming during R/O Week.

Housemasters and Graduate Residents

As a vital link between the students living in the dormitories and UESA, the Housemaster/Graduate Resident Program has had a productive year. A series of workshops were implemented throughout the year to provide in-service training for them on issues such as eating disorders, alcohol in the MIT culture and creating a safe space for students.

One of the most noteworthy events was the publication and community-wide distribution in March 1992 of the Baker House and East Campus House Survey on Harassment. As part of this effort to report on and inform the MIT campus about this issue, Housemasters and Graduate Residents conducted discussions with residents of their floors in order to follow-up on the report's distribution.

There are changes in three Housemaster appointments for this coming year. Dr. Charles Stewart III of the Political Science Department and Kathryn Hess of the Civil Engineering Department will take over as Housemasters of McCormick Hall from Drs. Graham and Janet Walker, who have served since 1986. Dr. Anne and William McCants of the History section of the Humanities Department will take over as Housemasters of Green Hall from Drs. Allison Hubel and Gregory Brown, who have served since 1989. And finally, Professor Halston Taylor of the Athletics Department and Katherine Dabulis of the Biology Department will take over as Housemasters of Random Hall from Dr. Irwin and Gloria Pless, who have served since 1980. We would like to thank all those leaving for their years of contributions and service to MIT life.

In addition, 18 Graduate Resident/Tutors left their positions at the end of this year and we welcome those selected as their replacements.

House Fellows Program

Adding five new Fellows, this program continued facilitating interaction between faculty members and residents of four undergraduate and two graduate dormitories and nine independent living groups.

Fraternities, Sororities and Independent Living Groups

Working with the MIT Safety Office, this year RCA established minimum life safety standards for the 34 Independent Living Groups. Each residence will be required to meet the standards by September 1993 in order to remain MIT approved housing. The estimated $1.2 million in life safety renovations include improvements to each house's electrical distribution, fire detection and alarm systems, egress, and the addition of central station monitoring capability. The improvements are being paid for by each of the living groups primarily through loans obtained through MIT's Independent Resident Development Fund.

Alpha Phi, MIT's first housed sorority, successfully completed its first year of residence in its new house on 477-479 Commonwealth Ave., Boston.

Campus Activities, Undergraduate Association and Finance Board

There were two primary areas where significant progress has been made. First, a private party registration form was developed and has proven remarkably successful. Working with the Campus Police, we believe all parties where alcohol is being served are now being registered with our office. This means that sponsors of such events are required to meet with a member of the RCA staff and review policies and procedures regarding the dispensation of alcohol. It is our belief that the reduced number of incidents involving alcohol can be attributed, in part, to this program.

Second, the first year of operation of the relational database developed for student activity accounts was extremely successful and resulted in increased efficiency and effectiveness in monitoring and reporting for those accounts. This summer the second phase of the database is being developed to include the Finance Board process, and the entire database will be upgraded to multi-user for increased access and data entry ability. Along with the completion of this development, the impact on its implementation on the funds distribution process is being discussed.

Fiscal Year '92 has seen financial activity comparable to the previous year in the Student Activity group accounts. For the Undergraduate Association (UA) expenditures, a particularly dedicated and efficient Finance Board chairman was responsible for the distribution of an unusually large percentage of allocated funds, including over $6,000 in allocated funds that had not been distributed in the previous year. The coming year's board will continue to focus on supporting student organizations and is currently discussing a streamlined process that will result in an improved allocation system.

Discipline and Harassment

This year the RCA staff dealt with more than 90 disciplinary cases, including approximately 55 involving harassment. This represents a slight increase over last year in the total number of cases and a significant increase in harassment cases reported to this office, continuing that trend from previous years. These cases included incidents and/or charges of assault with a dangerous weapon, domestic abuse, dating violence, theft, and computer and sexual harassment. Sanctions imposed ranged from verbal warnings, restitution for damages, community service, probation, declaration of Persona Non Grata at MIT, and recommendations of expulsion and suspension to the President.

As noted above, the Baker House and East Campus House Survey on Harassment was distributed community-wide in March in conjunction with student discussions in both the dormitories and Independent Living Groups. Continuing this effort to provide information to the MIT community, the Independent Living Groups and McCormick Hall were surveyed this Spring.

Talbot House

The major event this year in Talbot House operations was the implementation of a septic system on land owned and graciously allowed for use by Mr. Lawrence Rockefeller. The interior refurnishing was also completed.

Staff Changes

Assistant Dean Stephanie Harriston-Diggs was recruited for a CASE internship in Resource Development at Harvard University and will return to MIT next year. Michael Wolfson was hired as Staff Assistant for Residence Programs to coordinate the Graduate Resident/Tutor program this year and Dr. Mary Ni was selected to fill the position of Assistant Dean beginning next year. Christine Simmons was promoted to the position of Administrative Assistant and Mary Beth Damm hired for the part-time Senior Office Assistant position left open. Adam Goodie was hired for the UA Senior Office Assistant position and left after one year to pursue graduate study. Susanna Hinds, Director of Campus Activities, left to pursue other interests.

JAMES R. TEWHEY
NEAL H. DOROW
ANDREW M. EISENMANN
STEPHANIE HARRISTON-DIGGS
SUSANNA C. HINDS
ELIOT S. LEVITT
SHARON P. SHEA
MICHAEL A. WOLFSON

ROTC

The three ROTC units at MIT report to the Dean for Undergraduate Education and Student Affairs. This has been a year in which we have established some new relationships and communication links which will be useful as we proceed into a future in which the size and role of the ROTC program will inevitably be modified. The reports of the three independent units follow.

Air Force ROTC

The Air Force Reserve Officer training Corps (AFROTC) program at MIT provides challenging and comprehensive leadership and academic training for students attending MIT, Harvard, Tufts, and Wellesley. We continue to recruit and commission men and women as 2nd lieutenants in the United States Air Force. Year-end enrollment in AFROTC as of June 1992 was as follows:

	Freshmen	Sophomores	Juniors	Seniors	Total
MIT	14	16	11	15	56
Harvard	5	0	0	1	6
Tufts	0	1	0	6	7
Wellesley	0	0	0	0	0
Total	19	17	11	22	69

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

Highlights from AY 91/92 follow:

- The Freshman Orientation Program was run at MIT and Griffiss Air Force Base, New York, from 22 to 28 Aug. 91.
- In the fall term, Professor Meyer lectured and Col. Craigie/Mr. Lindley led the recitations for the second year of 17.471, American National Security Policy, to 43 students (21 were non-AFROTC).
- Col. Shapiro, Northeast Region Commander, visited the detachment on 22 Oct. 91.
- Major General Rosenberg (USAF-retired) was the guest speaker at the Dining-In on 22 Nov. 91.
- Detachment 365 sponsored a field day at MIT on 29 Feb. 92 for cadets from other detachments in the surrounding area.
- Brigadier General Tomow (AFROTC Commander) visited MIT on 18 Mar. 92.
- The Air Force approved time to pursue advanced degrees for all eight from MIT who requested this program (included one to medical school; two to law school).
- Twelve MIT cadets received commissions as 2nd lieutenants on 31 May 92. Three seniors required additional academic work to earn their MIT degrees.
- The AFROTC program provided MIT cadets with over $900,000 for tuition for AY 91/92.
- The cadre for AY 91/92 included Col. Craigie, Maj. Lambert, Maj. Levias, Capt. Danley, TSgt. Keller, SSgt. Oliveira, Miss Park, and Miss Wenger. Maj. Levias and Miss Wenger are leaving to pursue other assignments and job opportunities. Capt. Crider is scheduled to join the cadre in Aug. 92.

COLONEL RONALD P. CRAIGIE

Army ROTC

The 1991-92 Academic Year took on special significance for the department of Military Science. June 3, 1991, marked the 75th anniversary of President Woodrow Wilson's signing of the National Defense Act of 1916. This Act established the Army's Reserved Officer Training Corps (ROTC) as we know it today. Although the Department of Military Science here at MIT dates back to the opening of the school in 1865, the Army ROTC program was not officially established and recognized until 1916. The year was an extremely active and productive one for the Army Program. It began with the arrival of two new officers: the detachment Administrative/Logistics officer, Captain Tony J. Palmero Jr. and the detachment Training Officer, Captain Peter K. Sherrill. In early January 1992, the detachment received a Brigade Level Command Inspection (BCI), in which no deficiencies were noted. In April 1992, the Paul Revere Battalion hosted a one day visit by the Commanding General of Cadet Command, Major General Wallace C. Arnold. He was the first Cadet Command Commander to visit MIT, since Cadet Command was formed in 1986.

Enrollment

Over the academic year, a total of 80 students participated in our program, and at year's end, 65 of those students were still enrolled. Of the 65 Cadets, 8 (13%) were females.

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

	Freshmen	Sophomores	Juniors	Seniors	Total
MIT	6	4	5	12	27
Harvard	2	6	1	10	19
Tufts	7	6	3	1	17
Wellesley	0	0	2	0	2
Total	15	16	11	23	65

Of the 27 MIT students enrolled, 24 are currently recipients of Army ROTC scholarships. These scholarships pay 80% of tuition and 100% of fees; provide a monthly allowance of $100; and contribute once-a-year textbook allowance of $450.

Commissionees

This year the Army ROTC Department commissioned 22 new second lieutenants, eleven of whom were from MIT. Of the 22, five are entering graduate school, five will be reporting to active duty, and twelve are serving in the Army Reserve.

Extracurricular Activities

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

On- and Off-campus learning opportunities both continued to expand. Cadets trained voluntarily at Fort Benning, GA (Airborne); Ft. Campbell, KY (Air Assault); and Germany and other US posts (troop leadership). Participation continued strong in the MIT Pershing Rifles Company, a group of both ROTC and no-ROTC students dedicated to the pursuit of military tactical excellence and patriotism. The ROTC Faculty Committee, under the new chairmanship of Professor Kenneth Manning, continued to provide timely advice and support of the ROTC programs.

LIEUTENANT COLONEL GERALD T. WELLMAN

Navy ROTC

The Naval Reserve Officers Training Corps (NROTC) program at MIT provides challenging and comprehensive leadership and academic training for students attending MIT, Harvard, Tufts, and Wellesley. The Program encourages academic achievement, while providing practical experience, to provide the Navy and Marine Corps with capable officers. In the 1991-92 Academic Year, a total of 40 graduating men and women were commissioned. Program enrollment just prior to June Commencement was:

	Freshmen	Sophomores	Juniors	Seniors	Total
MIT	23	12	15	18	68
Harvard	12	15	11	13	51
Tufts	5	5	6	8	24
Wellesley*	0	0	1	1	2
Total	40	32	33	40	145

* Wellesley discontinued as cross-enrolled school beginning with class of '95.

The Navy's financial assistance totaled approximately $2.24 million for the year, including about $1.1 million for MIT students. Approximately 89% of all NROTC students and 92% of MIT students receive full tuition, payment for books, and a monthly stipend. Enrollment has declined to 145 from the 174 reported last year. Part of the decrease stems from a reduced number of NROTC scholarships granted nation wide for the class of '95 which resulted in a freshman class 20%

smaller than last year. Most of the remaining decrease is due to high attrition the class of '94 from last year to this year. Most of this attrition was at the students' own request.

Activities

Annual activities were highlighted by the Tri-Service Pass in Review on April 15, at which President Vest participated as senior reviewing officer. A Tri-Service Commissioning ceremony was held aboard USS Constitution on June 1. Astronaut Marine Colonel Kenneth Cameron (MIT '78) was guest speaker, and President Vest was included in the official party.

Visits

Vice Admiral John Fetterman, Jr., Chief of Naval Education and Training visited the unit and the MIT campus in April. VADM Fetterman called on the President, the Provost, and the Dean for Undergraduate Studies. The visit was constructive, from the Navy's point of view, and very successful.

Sexual Harassment

Prevention of sexual harassment continues to be a point of major emphasis within the Navy and the NROTC Program. A series of workshops and formal discussions on the matter were held during the fall and spring semesters. All NROTC students and staff were required to attend. Additionally, a guest speaker addressed all NROTC personnel on date rape. My policy is to ensure maximum awareness and sensitivity on this issue. There have been no reported incidents of sexual harassment involving midshipmen or NROTC staff.

Consortium

Implementation of the consortium arrangement with Boston University (BU) will be completed during the summer of 1992. From the students' point of view, changes stemming from the consortium arrangement will be minimal. One or two extra-curricular activities, such as holiday parades and/or military assemblies may be held jointly, but for almost all routine functions it will be business as usual. I have appointed two students from the MIT Unit and two from BU to a newly created regimental staff to coordinate the relationship between the units as necessary.

Any additional burden generated by the consortium arrangement will be felt exclusively by the active duty NROTC staff. I have been double-hatted for an entire year now as Professor of Naval Science at both MIT and BU, and my Executive Officer, CDR David Finch, has been double-hatted in his position since relieving CDR Watkins in early June. Major Huelskamp, who relieves Major Mark Shafer as Marine Office Instructor in July 1992, is the only other officer who will be double-hatted. The staffing level for individual class advisor positions will not be changed.

CAPTAIN MICHAEL E. FIELD

STUDENT ASSISTANCE SERVICES

Over time the writing of reports on the activities of Student Assistant Services takes on a certain repetitive quality. Our charge remains what it has been for the last decade: to support the activities of students-American and International. We continue to do that with high volume of student traffic a constant. We see about ten percent of the undergraduate community each year on counseling matters and all new international students pass through the office at least once. Other internationals come and go with regularity. In addition we see numbers of students from the particular communities we have mandated responsibility for: i.e. minority students, women, disabled students, gay and lesbian students. This traffic makes this office a bellwether for reading trends on campus.

Several trends from the past year stand out. We have seen a growing number of students taking time away from MIT specifically for economic reasons. It appears that rising costs and the economy have finally begun to make a significant impact on student's decisions to remain at MIT. There is no way of measuring how much economic factors influence the academic performance of students who are required to withdraw since it is hard to get beyond obvious academic difficulties, but the sense of the office is that this problem is also increasing.

Tensions in the world create problems for students at MIT in increasing numbers. Seldom have we had so many crises at the same time. A year ago we were recovering from the effects of the war with Iraq and its implications on students and their families. The situation in Yugoslavia continues to impact the lives of students; so too with famine and strife in portions of Africa; the ebb and flow of prospects for peace in the Middle East have immediate implications for members of our community; each change of tone in China touches students at MIT.

There were no suicides during the past academic year, but this hardly qualifies as a trend. I note it because as I was writing this report last year we were reeling from two student deaths that forced us to rethink our response to tragedy in our midst.

In specific areas the following items are noteworthy. Dean Ayida Mthembu saw work done in previous years come to fruition this past year. The third annual Kwanzaa week, Black History Month and Hispanic Month were all extremely successful and students carried a greater part of the responsibility. Hispanic Month was a new activity that should be repeated. This year was also noteworthy for the four Black artists in residence who spent time with students: Dessima Francis of Roxbury Outreach Shakespeare Experience, Toni Cade Bambara, writer/film maker, visual artist Valerie Maynard and Jerry Butler who was a visiting professor in the Drama Department.

Dean Milena Levak and the International Student Office continued to carry a heavy load of student traffic made worse by changing rules and regulations promulgated by the Immigration Act of 1990. Regulations that went into effect in the fall of 1991 nearly ended opportunities for summer off-campus work traditionally enjoyed by foreign students. Each change in regulations results in work for the office as we have to both communicate the change and mediate its implications. This year we also had an enhanced orientation program for over 800 new foreign students to help prepare them for life at MIT.

Our population of students with disabilities is continuing to expand and so has the work of Dean Arnold Henderson. As numbers of students have grown so has his involvement with prospective students, interested parents, social agencies, businesses, and current students who often do not self-identify when admitted. The Americans with Disabilities Act has raised the awareness of many to their peers with disabilities. This important part of our area of responsibility becomes larger each year.

Support for Women Students continues to be a major focus in the office. Dean Jackie Simonis and Lynn Roberson began the year with an intensive orientation program and through-out the year there were programs and presentations designed to make the life of MIT women easier. Dean Simonis continued to over-see the successful Nightline peer hotline and is also helping to bring into being Contact Line which will deal with issues of sexuality for the community.

Kate Baty brought the Host Family Program into the office in the summer of 1991 and with smoke and mirrors carried out a successful program that will need more support and funding as it expands.

The year has been an extremely rewarding one since for the first time in several years our personnel remained constant for most of the year. With continuity comes the confidence and maturity needed to try new ideas and to take risks. We did some of both this year with the Host Family Program, with the more complete orientation programs in the ISO and with new efforts for women and the minority community. Our stability, as is to be expected, did not last and we will have lost several important members of our office by the end of summer. Debbie Herman left the office for health reasons and Pengbian Sang is returning to his home in the Dominican Republic. Replacing them will be difficult, but offers the opportunity to gain some new perspectives with new faces.

ROBERT M. RANDOLPH
DANIELLE GUICHARD-ASHBROOK
ARNOLD R. HENDERSON
DEBORAH HERMAN
MILENA L. LEVAK
AYIDA MTHEMBU
LYNN A. ROBERSON
JACQUELINE R. SIMONIS
BRIMA A. WURIE

UNDERGRADUATE ACADEMIC AFFAIRS

The office now called Undergraduate Academic Affairs began the 1991-92 academic year as two distinct entities, the Undergraduate Academic Support Office (UASO) and the Office of the Dean for Undergraduate Education (ODUE). Following the death last fall of Professor Margaret MacVicar, Dean for Undergraduate Education, the February 1992 merging of ODUE with the Office of the Dean for Student Affairs under Professor Arthur C. Smith, as Dean for Undergraduate Education and Student Affairs, specifically linked most ODUE functions with those of UASO under the new name UAA, with Professor Travis Merritt as its head.

The months preceding and following this merger have been marked by a numbing sense of shock over the loss of Professor MacVicar, and by some anxieties and growing pains as a combined staff of twenty-five (twice the size of either group prior to the merger) has sought to establish a genuinely collaborative structure, adjust collective goals and priorities, and build new working relationships among a diverse gathering of individuals. These efforts have so far been rewarded in an organization which promises to extend and to realize more fully the complementarities of mission which for several years have been recognized in an increasingly cooperative relationship between UEO and UASO. In particular, the most impressive of these consequences has been a closer and more complete affiliation of programs which support and enrich student academic life with those which enhance the educational work of the faculty.

From the outset, the newly combined staff has found itself in enthusiastic consensus on one overarching principle: that UAA should move beyond the providing of services and enlarge its role as an assertive agent for change in MIT's undergraduate educational system. This dictates quite expressly a need continuously to renew and augment the office's interaction with the Institute faculty, not only through existing school and departmental hierarchies and the structure of standing committees, but also through persistent individual contact.

During 1991-92, UAA carried forward its work in these broad areas: academic advising, curriculum support, faculty and teaching development, educational studies and research, the Undergraduate Research Opportunities Program (UROP), the Independent Activities Period (IAP), the Undergraduate Seminar Program, the Writing Requirement, the MIT Colloquium, the Wellesley-MIT Exchange, and Residence/Orientation (R/O). In the report which follows, however, we have omitted the usual routine accounts of activities that more or less did business as usual, focusing instead on developments worth particular notice.

Academic Advising

The academic advising function is one of UAA's prime responsibilities. This includes providing academic advising for freshmen and undesignated sophomores, as well as individualized academic counseling for all undergraduates. Advisors and counselors assist students in their selection of subjects and help keep them informed about their academic standing, lending assistance to those who run into difficulty, and offering useful programs on study skills and time management. This year brought two significant changes in organization and policy designed to strengthen this function. The first of these was the establishment of a Freshman Advising Center in 7-104, a move which sharpens UAA's visibility as the academic headquarters for first-year students. The Center, jointly staffed by six administrators, coordinates the extensive system of freshmen advisors, the Associate Advisors program, the Freshman Advisor Seminars program, CAP liaison, on site help for students with special problems, and the study skills offering. A second change, planned and being implemented for the Class of 1996, eliminates "regular" advisors from the array of advising options, ensuring that all freshman advising will be fortified through linkage with either instruction (Freshman Advisor Seminars) or living groups (Residence-Based Freshman Advising). It is estimated that about 80% (c. 900) of incoming students will be enrolled in FAS next Fall. The remaining 20% (c. 225) will be in RBFA, which for 1991-92 is being extended to all of MIT's 43 living groups. In another noteworthy step, the Associate Advising program underwent a series of improvements this year through efforts to provide freshmen with more consistent and informative advising from their upperclass Associate Advisors, and to strengthen the working relationship between these students and the faculty/staff advisors with whom they are teamed.

Freshman Advisor Seminars. The number of Freshman Advisor Seminars rose from 66 to 93 this past Fall, accommodating 740 of the 900 freshmen who applied for them. For the first time in the six year history of the Freshman Advisor Seminar program every academic department and section was represented, involving 91 faculty (including the Provost, two Associate Provosts, four Deans of Schools, and one department head) and 9 administrative staff. As a result of a successful recruiting campaign this year, we'll again break the record with 128 Freshman Advisor seminars for Fall 1992, of which 40 are being offered by first-time leaders. The success of the FAS program cannot be measured in numbers alone. The relative ease with which faculty can now be persuaded to take on this considerable task (many are actually spontaneous volunteers!) is evidence that the idea has gained widespread acceptance as an enhancement not only of the advising process but also of the intellectual life of MIT students in their first year. An advisor seminar gives the freshman a refreshing change of pace and content from the core curriculum, a welcome intimacy of instructional scale, and a chance to form first friendship with a faculty member. For the faculty leader, it is an opportunity to try something new and to brush up discussion-style teaching skills, while gaining a close-up view of the whole freshman experience that is otherwise hard to come by. Perhaps most significantly, the prospering of FAS can be seen as a first major step in what we hope will be the progressive enrichment of freshman education through extensive use of interactive learning in *very small groups* (vsg). (For more on this, see Curriculum Support below). In May, the FAS program received the Irwin Sizer Award as the most significant improvement to MIT education, and we are proud of that. We are also aware, however, of the need continually to support and upgrade the quality of these seminars, especially in helping leaders to cultivate the art of discussion and find the right synergy of assigned work and fun.

The Committee on Academic Performance. CAP was chaired this year by Professor George F. Koster. The Committee continued its policy of not approving exceptions to the Freshman credit limit. The fact that only four petitions to exceed were submitted indicates that freshmen now understand well the strength of CAP's resolve. In recognition of the unique educational role of Program XL, however, the Committee this spring unanimously endorsed an experiment, proposed by Dean Smith, which for 1992-93 will allow a freshman who elects XL to modestly exceed the fall term limit.

The most important news contained in the statistical profile of Committee actions is that the number of CAP Warnings issued to freshmen, which had more than doubled in 1990-91 over previous levels, declined by one-third (from 223 to 148) in 1991-92. In the absence of other significant variables, this change strongly suggests that this year's freshmen have adjusted far more realistically than their immediate predecessors to the two-year-old redefinition of PASS as performance at

grade C level or better. It is quite likely that the newly instituted Math Diagnostic (see Curriculum Support below) played some role in this welcome adjustment.

Curriculum Support

The task of those of us associated with Curriculum Support has been dedicated to promoting "a climate of 'why not?' and an excitement for experimental possibility" as envisioned by Margaret MacVicar. Our objectives have always centered on providing the encouragement and support necessary to enable faculty to participate actively in curriculum development and reform. Activity for 1991-92 included: continuing our strong coordinating role designed to strengthen interactions among the departments of Mathematics, Physics, Chemistry, and Biology and their share of the first year science subjects; providing special support to the Committee on the Undergraduate Program this year. We attempted to chronicle the circumstances and concerns leading up to the current unease with the undergraduate program requirements (in a document titled, "Agenda for an Educational Review"). Worth special note are the following:

The Pre-Calculus Math Diagnostic. One year ago, planning was underway to administer during R/O Week '91 a pre-calculus mathematics diagnostic test to the entire freshman class. The primary goal of the effort, led by our office, was to get students better prepared to deal with the first term at MIT by providing them and their advisors with information about deficiencies in their math background and to give them timely help. In addition, it was hoped that the results of the diagnostic would provide a basis for further discussion about students' math preparedness for the science core subjects. Over the summer, incoming freshmen were mailed a practice "self-test," and a series of five pre-calculus math modules were developed to send to students who wanted to review before coming to MIT. A second test, similar to the one sent during the summer, was administered to the entire freshman class at the beginning of R/O Week. Results were given to the students at the first meeting with their freshman advisors; those identified as weak in one or more of four areas (algebra, geometry and analytic geometry, trigonometry, and logarithms and exponentials) were directed to "Math Brush-Up Nights" — evening review sessions staffed by tutors and organized by our office with the able assistance of Dr. Peter Dourmashkin.

It was not clear to what extent the unexpectedly large number of low scores could be attributed to genuinely poor preparation as opposed to a merely casual attitude. In collaboration with our Educational Studies colleagues, we looked at both first quiz and end of fall term performance data to determine whether there was a relationship between performance at MIT and diagnostic score. The subsequent analysis of this data has convinced most faculty that the diagnostic is useful as a measure for predicting first term performance, at least in physics: students who did badly on the math diagnostic tended to fare worse and failed more often in 8.01 than students who had scored higher. (By second term, however, the relationship is diminished, though still apparent.) This evidence stimulated the Physics department to design a new version of first term physics (8.01L) to be offered to incoming students next fall. In addition, we have decided to strengthen the statements made to next year's freshmen about the importance of pre-calculus skills, have begun planning for a more extensive program of review sessions, and are working with the Mathematics Department on their plan to require passing of a pre-calculus math test as a new unit in all first term calculus subjects.

Improving Recitation Sections: vsg's (very small groups). During the winter, we talked with a number of instructors teaching subjects that offer interactive small group sections ("tutorials") in some of the engineering departments. We wanted to know: was the tutorial-section model transferable to core science subjects? At the heart of our investigation was a desire to explore alternatives to the standard recitation section format. (The success and popularity of intimate scale in the Freshman Advisor Seminars is relevant here as well.) We are convinced that the recitation section model can be improved — in terms of both class size and the level of interaction that takes place among students and with the recitation instructor. We proposed an experiment with small-group, interactive sections — *vsg's* — to the Physics department. The premise of our proposal has provided the basis for a number of stimulating discussions about how first year students are taught. We look forward to working with the Physics department as they undertake a review of first year physics.

Faculty and Teaching Development

One clear benefit from the UEO-UASO merger has been the opportunity for several staff members earlier involved more or less independently in various aspects of faculty development and the promotion of quality teaching to form within UAA a unified team with a more purposefully integrated agenda. Drawing together elements formerly scattered under several headings — e.g. Curriculum Support, R/O, Course Evaluation Guide, IAP, the MIT Colloquium, and Educational Studies and Research — the program in Faculty and Teaching Development has already moved to provide facilitating services at the Institute level and to support existing activities within the departments and schools, in collaboration with the offices of the Associate Provost for Institute Life and the Dean of the Graduate School. It is certain that the MIT Colloquium's year-long focus on more effective instruction (see MIT Colloquium below) significantly raised the community's consciousness of the need for such efforts.

Current undertakings, often in collaboration with departments, schools, and other MIT offices, include: the orientation workshop for new faculty and graduate teaching staff; visits by UAA staff with all new faculty during their first year to welcome them to MIT, make sure they know about resources and programs, learn of their ideas and needs, and benefit from their fresh view of the Institute's undergraduate program; compilation of accounts of college TA training efforts throughout the nation, as a centralized resource for departmental and Institute-wide exertions along these lines; a thorough canvass of all departments to learn of their existing and projected activities in the area of improving teaching effectiveness, and to develop UAA coordination with key faculty and departmental committees working in this area; seminars and workshops on teaching-related topics with the School of Engineering's Faculty Instructional Resources Program (FIRP); classroom videotaping and feedback; discipline-specific orientation for new instructors in freshman core mathematics and physics subjects; upgrading the *Course Evaluation Guide* (CEG) and coordinating its function with the other forms of evaluating teaching. Undertakings for the longer term include: development and publication of a Faculty Resource Guide for Teaching (already in the works); formation of a faculty Working Group to Improve Teaching Effectiveness; updating and reissuing *The Torch or the Firehose*; encouraging other departments to build intensive and sustained September workshops for TA's like the admirable one now being orchestrated in Chemistry; establishment of a regular relationship with the Bok Center at Harvard to learn more about proven ways to enhance teaching skills.

The creation of Faculty and Teaching Development as a nominally and organizationally distinct operation is meant to strengthen and augment the effectiveness of Curriculum Support, in which it is deeply rooted. These programs must continue to be intimately related in a natural symbiosis which we believe will be mutually beneficial to each.

Educational Studies and Research

In the reconfigured organization of UESA/UAA, the position of Director of Educational Studies has not yet been filled, pending careful deliberations on the future role and location of institutional studies at MIT. Nonetheless, during 1991-92 a good many initiatives in this area were either carried forward or begun, under the leadership of several UAA staff and often in conjunction with other individuals and offices around the Institute. These include: tracking studies of academic performance by underrepresented minority students, and ongoing assessment of Project Interphase, conducted for the Office of Minority Education (OME); student and faculty surveys on academic dishonesty for the MIT Colloquium; continuing studies of Independent Activities Period (IAP); correlation of Math Diagnostic results with academic performance at MIT; studies of HASS-D enrollments and the undergraduate HASS experience, conducted for the School of Humanities and Social Science; assessment studies of actual MIT student workload in relation to the credit-unit system; networking and coordinating of research efforts through the Educational Studies Working Group (ESWG).

UAA's direct and facilitating involvement in educational studies is integral, we believe, with this office's role in academic affairs. Institutional self-scrutiny through methodologically sound research, usually undertaken at the request of a school, department, or faculty committee, is in practice a highly collaborative and synthesizing activity. It is done in the interest of validating or changing existing policies of great scope, to aid curriculum experimentation and innovation, and to examine local issues germane to specific academic programs. Because its reach and variety are so extensive, and the energies which prompt it so often spring from diverse local soils, educational research cannot of course be regarded as the exclusive responsibility of any single office. On the other hand, it seems clear that the MIT community will continue to generate a wide range of studies reflective on its academic mission, and that some central agency should exist to support, keep track of, coordinate, and stimulate these efforts as appropriate. In the absence of a special Institute office created expressly to serve this purpose, history and common sense suggest that UESA/UAA should continue to be its home.

UROP

It has been a sad year for UROP, with the death in early fall of its founder Margaret L. A. MacVicar, Dean for Undergraduate Education and Professor of Physical Science. Dean MacVicar was devoted to MIT, and was tireless in her efforts to improve undergraduate education and improve the teaching environment for faculty. Of all her many contributions to the Institute, UROP is her most visible legacy. In the more than twenty years of its existence it has become part of the daily life of the Institute, and now plays a significant role both in the education of undergraduates and the professional lives of the faculty who supervise them.

This year student participation reached new heights in nearly all departments and interdisciplinary laboratories, both during term time and summer. The number of students actually supported for the summer of 1992 (using figures available at the end of fiscal year 1992) was 13% more than last year. Overhead was waived in fiscal year 1992 (including 1991 summer figures) on over $3.8 million of sponsored research funds. At the recent rate of increase, we expect this number to reach $4 million by next year. In the coming years the brand new and barely completed data base system developed for UROP will give us vastly improved record keeping and statistical information.

In another two years UROP will mark a quarter century anniversary. It has retained a sense of excitement all these years, and it is our hope this will never change. It is important that UROP continue to serve faculty and students equally well.

We need to continue to make special efforts to reach junior faculty (often our most enthusiastic supervisors), and to reach and encourage inexperienced students. We hope to build in mentoring of first time UROP students by upperclass students, expanding on efforts tried in the past on a small scale. We will encourage pre-research seminars — including Freshman Advisor Seminars — so that students can learn about the issues in a given area, or learn about laboratory procedures, before they make a formal UROP commitment. We will promote greater use of IAP for research or pre-research experience by beginners. We need to continue to strengthen ties to the curriculum, whether this be by increasing connections between UROP and hands-on or engineering design possibilities, or opportunities for writing, for interdisciplinary work, or for curriculum reform. Above all, we must remain flexible and responsive to changing conditions. We are committed to tending UROP with the same spirit in which it was founded.

IAP

In IAP '92 faculty and students maintained the increased commitment to sustained academic activities that has characterized IAP for the last four years. The faculty are awaiting the recommendations of the Presidentially-appointed Calendar Committee considering changes to MIT's academic calendar, including IAP. This committee, chaired by Professor Robert Silbey, will be issuing its report in the fall and indications are that it will recommend that IAP be lengthened to four weeks. Professor Linn Hobbs, chair of the IAP Policy Committee, is serving as a member of the Calendar Committee.

This past spring the IAP Policy Committee developed a Statement on Credit-Bearing Activities urging MIT to continue with vigor its efforts to offer more sustained academic activities and credit-bearing subjects during IAP, particularly six-unit subjects and those with low student/faculty ratio (15 to 1 or smaller). The committee also recommended that departments offer more subjects giving students the option of fulfilling requirements during IAP.

With a total of 611 activities in IAP '92, the number of credit-bearing activities rose slightly to 69, compared to 63 in IAP '91. However, the number of undergraduate grades awarded dropped to 916 from 1082. In a new survey of undergraduates, respondents reported spending on the average more than three-quarters of their IAP time at MIT (actually 78%), compared to 71% in 1990. Almost 70% of this year's respondents said they participated in *IAP Guide* activities, compared to 63% in 1990.

The Writing Requirement

The Committee on the Writing Requirement has been working with departments to ensure a consistent standard of evaluation throughout the Institute and has made several substantial modifications to the Requirement. The Committee, with the unanimous consent of departmental writing coordinators, abolished the category of "Marginal Pass" for both Phase One and Phase Two papers. The Committee, with the concurrence of the Committee on the Undergraduate Program, also modified the conditions under which students receive Phase One credit for completing a specified writing subject. Beginning with the summer of 1992, students in Phase One Writing subjects will complete Phase One only if they are certified by the instructor as proficient in expository writing. Previously, students receiving a grade of C or better automatically completed Phase One. Further, beginning with the Class of '96, all entering students who have not already completed Phase One will be required to take the Freshman Essay Evaluation. The purpose of this change in policy is to ensure that potential writing problems are diagnosed early in a student's career at the Institute. The Committee has also authorized several experiments concerning the scoring and grading of the fall 1992 Freshman Essay Evaluation that will allow greater accuracy in assessing and remedying certain types of writing problems.

New Writing Initiatives. The Writing Requirement, as it is presently constituted, has been effective in ensuring a minimum level of writing competency among MIT undergraduates. Although effective in meeting this goal, the Requirement is not sufficient to ensure that MIT undergraduates leave the Institute with the oral and written communication skills necessary for their full professional and personal development. Several educational initiatives are being developed that would enhance the analytic and communication skills of undergraduates by providing new learning experiences that would stress frequent writing and revision and small-group interaction. The Coordinator of the Writing Requirement has been involved in the planning of "writing-intensive" HASS subjects and "writing extensive" subjects in the school of Engineering. These initiatives would create new options that would make the current Writing and HASS Requirements more flexible and effective.

MIT Colloquium

A new policy has been established for the MIT Colloquium. Instead of offering colloquia in the fall and spring, there will only be one in the fall, under the aegis of the President and Provost, with year-long follow-through on the topic. We expect to involve MIT's academic departments more directly than in the past.

The October 1991 Colloquium. As the final event of the Presidential Inaugural Year, the Colloquium in October, *Teaching Within a Research University,* was in many respects the most successful one so far and drew record crowds — an

estimated 1500 people. Former Massachusetts Governor Michael Dukakis acted as the "interlocutor" to a panel of 10 from MIT representing all 5 Schools, including faculty and researchers, the deans of the Schools of Engineering and Science, and a graduate and undergraduate student. Governor Dukakis skillfully prompted the panel to discuss some of the issues facing MIT and other research universities with regard to the balance of teaching and research. Unlike previous colloquia, in which after the Kresge presentation the audience dispersed for dinner and discussion to the student living groups, this year the smaller sessions were hosted by 23 of the academic departments, since the practical implications of the topic were specific to particular disciplines. A major concern raised by undergraduates and graduate students, both in the plenary assembly and during the dinner/discussions, was the alleged poor quality of teaching in undergraduate subjects by many faculty and graduate student teaching assistants. As a practical sequel to the Colloquium and as one way to address this concern directly, a set of experimental workshops on discussion method teaching was offered over three consecutive days during January IAP. The aim of these workshops was to provide a forum where faculty, graduate and undergraduate students could come together as equal participants in a small-group learning situation to hold a discussion on an actual intellectual topic and then reflect on and analyze how the discussion went. In the spring term each academic department was asked to engage in a formal follow-up to the Colloquium, by planning a department gathering of faculty, staff and students to take stock of what advances had been made during the year in promoting high-quality instruction and to set agendas for further action.

Residence Orientation (R/O)

In addition to the usual array of well-received programming, R/O 1991 brought a couple of innovations worth notice. One was a much enlivened version of the Academic Convocation, in which the Provost played game-show host as freshmen answered non-trivial questions about academic matters. High spirits prevailed, and information-flow was good. More important, the kickoff for R/O introduced a new event, Project MOYA (Move Off Your Assumptions), in which freshmen in groups of 12 got to know each other and something about themselves through closely interactive games and exercises designed to explore trust, build teamwork, and promote leadership. Not only was the event in itself extremely popular with the new students, it also set a tone of openness which noticeably prevailed throughout R/O.

This year one element of orientation extended several weeks into the term through a series of cabaret-style evenings of instructive entertainment in Lobdell Dining Room. *Wednesday Nite Live* addressed in varying formats such matters as sexuality, harassment, alcohol and drugs, and the dynamic of relationships. Attendance at the performances and subsequent discussions totaled about 1500 students, most of them freshmen.

TRAVIS R. MERRITT
STEPHANIE K. BARTLING
MARGARET S. ENDERS
MARY Z. ENTERLINE
DONNA L. FRIEDMAN
MAUREEN A. HORGAN
GREGORY A. JACKSON
ALICE M. E. LAPIERRE
ALBERTA G. LIPSON
NORMA G. MCGAVERN
JEFFREY A. MELDMAN
STEPHEN M. PATTERSON
LESLIE C. PERELMAN
CLAUDE J. POUX
DEBBIE H. SHOAP
BENSON R. SNYDER
BONNIE J. WALTERS
MOYA VERZHBINSKY

DEAN OF THE GRADUATE SCHOOL

FEDERAL SUPPORT ISSUES

The activities of the Office of the Dean of the Graduate School (ODGS) in the past year were dictated to a large degree by proposed changes in federal policy that have the potential to impact negatively on the support of graduate students. The most significant of these changes would disallow our current use of the employee benefit pool to distribute the tuition costs of research assistants (RAs) broadly across the Institute, and would presumably require us to charge that tuition directly to the associated research project account. The impacts of such a change in RA tuition policy would be to increase the cost of supporting RAs relative to full-time research and postdoctoral staff, and increase the cost of many research projects, especially those smaller projects whose costs are typically dominated by RA costs. Great concern was expressed that the long-term effects of such changes would be a significant reduction in the number of graduate students at MIT and a reduction in our production of doctoral degree recipients.

In response to this threat, the Provost established an ad hoc Faculty-Administration Committee on Indirect Costs and Graduate Tuition under the chairmanship of Professor Robert A. Weinberg. Dean Frank E. Perkins, assisted by Ms. Anjali M. Sastry, a graduate student member of the ad hoc committee, prepared detailed analyses of the potential financial impacts of possible new tuition policies. These analyses, which were incorporated into the final report of the Weinberg committee, demonstrated clearly the negative consequences of a change in our current tuition policy, and illustrated the tradeoffs that exist between raising the costs of RAs and of research contracts, and increasing the drain on Institute General Funds in order to contain these costs. At year's end, these tradeoffs were still under consideration and the federal government had yet to issue a definitive statement as to when and whether our current tuition policy will be terminated.

This past year marked a new chapter in our efforts to deal with the tuition shortfall associated with the many National Science Foundation (NSF) predoctoral fellows at MIT. For the first time, we chose to encourage the use of partial research assistantships (up to 1/4 time) as a mechanism for covering a portion of the shortfall, thereby making it possible to place a realistic limit on the amount of Institute General Funds required for that purpose. This mechanism had been rejected in previous years because of the excess stipend that it produces for the NSF fellowship recipient; however, it was adopted in the past year in recognition of the need to limit and in the future to reduce the program's demand for General Funds.

We were pleased to note that the cost-of-education allowance made on behalf of NSF fellows did increase to $7,500 from the $6,000 figure which had obtained for several years. However, we were troubled to learn in mid-year that a further increase which had been anticipated for 1992-93 was not going to be implemented because of budgetary considerations. This news was followed at year's end by reports that the Department of Defense, whose fellowship programs provided full support for more than 100 graduate students at MIT in the past year, was considering a cap on the amount of tuition they would provide in the future. These reports seem to portend a trend in which research universities will be called upon to cost share an increasing portion of the costs of research. Such trends have the potential to reduce the size and quality of our graduate student population and are a major source of concern.

The summer employment plans of many international students on F-1 visas were threatened by a change in regulations of the Immigration and Naturalization Service (INS). Dean Perkins and Associate Dean Milena M. Levak, International Students Adviser, developed a flexible procedure through which departments could document that a student's summer employment falls under the category of "curricular practical training" and thereby resolved this threat for a majority of those international students who were planning to work off campus. However, the existence of these new INS regulations was seen as just one example of a growing national perception that international graduate students represent a threat to domestic graduate students. Near year's end that perception was reinforced by Representative Paul Henry's introduction into Congress of a bill which is intended to restrict the use of international students as graduate RAs on federally funded research grants. Although the bill was rejected by a Congressional Subcommittee, efforts to garner support were still underway at year's end, and the national perception of a "problem" still remains. This is an issue that is likely to occupy our attention in the coming year.

COMMITTEE ON GRADUATE SCHOOL POLICY (CGSP)

In order to facilitate the conduct of its business, the CGSP was reorganized into three subcommittees. The subcommittee on Academic Policy, under the chairmanship of Professor William M. Deen, worked closely with the Registrar to resolve a myriad of detailed questions and opportunities presented by the new Student Information System which is expected to be implemented within the next two years. This subcommittee also reviewed our procedures for administration of interdepartmental degree programs in order to resolve questions that had arisen in the past year regarding the role played by a student's home department versus that of the interdepartmental committee. Wording changes designed to clarify these roles were proposed by the subcommittee and adopted by the CGSP.

The subcommittee on Academic Subjects and Programs, under the chairmanship of Professor Steven R. Tannenbaum, assumed the function of reviewing and acting with power on proposals for new and revised academic subjects. The

subcommittee also reviewed and approved a new doctoral program in Transportation Studies and MIT participation in a Women's Studies consortium. Preliminary review of the Leaders for Manufacturing Program was initiated and is expected to be a major topic in the coming year. Prior to establishment of the subcommittee, the CGSP had reviewed the Management of Technology Program and approved a new tuition structure for that program.

The subcommittee on Academic Performance, under the chairmanship of Professor Leon B. Groisser, reviewed our end-of-term grades meeting procedures and concluded that they should remain relatively unchanged. The subcommittee was also available to advise Dean Perkins and Associate Dean Isaac M. Colbert on problems associated with the academic performance of individual graduate students.

My colleagues in the ODGS and I wish to express our thanks and appreciation to members of the CGSP for their service during the past year. A special "thank you" is extended to the following members who will be replaced in the coming year: Eduardo Kausel (Civil Engineering) replaced by Ole Madsen, William M. Deen (Chemical Engineering) replaced by Robert E. Cohen, Mark Schuster (Urban Studies) replaced by Lawrence Vale, Ann Friedlaender (Economics) replaced by Franklin Fisher (fall term) and Jeffrey Harris (spring term), Harold Wachman (Aeronautics and Astronautics) replaced by Wallace E. Vander Velde (fall term only), and Merritt Roe Smith (STS) replaced by Ken Keniston.

This is an appropriate point at which to mention the efforts of the departmental graduate administrators who work closely with the official CGSP members. Monthly luncheon meetings of these administrators have proven to be most helpful in carrying out the duties of the ODGS. Particular mention must be made of Ms. Sharon A. Cayley and Debra A. Luchanin who organized this past year's luncheon series.

AFFIRMATIVE ACTION & OUTREACH

Sponsored Programs

The *Minority Summer Science Research Program* brought its sixth consecutive group of interns to MIT in June. Seventeen students attended the ten-week program and conducted research activities under the guidance of faculty and senior graduate students. From among the interns, three have applied to, have been admitted to and will matriculate into graduate programs in Biology, Chemistry and Mathematics at MIT in Fall, 1992. The seniors among the interns have all been admitted to graduate or medical programs across the country. We anticipate that for the program beginning in June, 1992, we will be able to offer, on a pilot basis, several internships in the School of Engineering. These intern slots will begin to realize our goal of extending the Summer Research Program into that school and thereby broaden the range of options available to potential interns. We are delighted that the School of Engineering has been eager to work with the Graduate School Office in offering this pilot. Nevertheless, the ongoing funding for this expansion will be a concern. We have proposed to the U.S. Education Department that the engineering portion of our program be supported under a Ronald E. McNair Post-baccalaureate Achievement Program. If successful, this grant proposal would support up to twenty engineering interns each summer for three years.

Activities for the *Minority Mentorship Program* consisted of a two-part series of presentations entitled "Aspire Higher." The series was designed as a part of our recruitment outreach activities to encourage undergraduates to consider the opportunities and challenges of a graduate education. For the first activity, held in late October and co-sponsored by the MIT Black Students Union, five minority alumni who are high ranking corporate officers or otherwise successful and visible professionals were invited to share their observations and reflections about their educational and career experiences. The second activity was held in April to provide students with specific information about applying for and financing graduate school. Both activities were heavily attended, provoked lively question-and-answer sessions and were well received by students.

Activities for the *Visiting Faculty Program for Historically Black Colleges and Universities* showed some very positive developments. Professor Sylvia Bozeman of Spelman College visited colleagues in the Mathematics Department and began to lay the groundwork for cooperative research activities involving her and her students. Moreover, following a visit to Clark/Atlanta University by Professor David Benney and Institute Professor Isadore Singer of the Mathematics Department, arrangements were crystallized for an extended visit to MIT by Professor Shabazz from Clark/Atlanta in the Fall Term, 1992. The program is therefore beginning to produce the kinds of productive faculty-to-faculty interactions that were envisioned, and the Mathematics Department is confident that a solid base for long-term relationships has been formed.

Recruitment and Outreach

Recruitment activities for the past year sought to capitalize on last year's distribution to departments of a Recruiting Resource Guide, which provided departmental graduate admissions committees with detailed information about historically minority and predominantly minority institutions across the country. With the information available through this resource, departments have been better equipped to evaluate applicants from these schools.

As a follow on to the availability of this resource, our African-American and Latino graduate students jointly conducted a series of telethons, one in early November and one in March. The November telethon sought to encourage minorities to apply to MIT graduate programs; and the second attempted to improve the yield from those who were eventually admitted.

Both telethons were successful in reaching students, and available data have indicated that the number of applications received from minority students increased significantly. It is not clear yet whether the yield was improved, and there are disturbing signs that the admissions rate remained unchanged from prior years despite the successful contacts with students. There would seem to be a need to work more intimately with departmental admissions committees to be sure that they have all the informational resources they need to evaluate fully the applications from minority students. A relevant pilot program is under development for implementation in the coming academic year.

Finally, MIT in collaboration with Clark/Atlanta University and a regional consortium on waste management is planning a major minority recruitment activity for Fall, 1992 in Atlanta, GA. This meeting will bring together students, faculty, department heads and administrators from the major research universities and from many of the historically Black colleges. The agenda will consist of research presentations and opportunities for colleagues from science disciplines to interact, but will also feature a working session in which participating faculty will develop new ideas about ways to improve the flow of minority students into graduate degree programs. If successful, the event will become an annual one.

INDIVIDUAL ACTIVITIES

Dean Perkins continued his work with the Association of Graduate Schools (AGS) in the Association of American Universities and was elected vice-president and president-elect at the annual meeting of the AGS in October. He will serve as president in the 1992-93 academic year.

Associate Dean Colbert was recently named to a two-year term as Co-Chair of The Cambridge Partnership for Public Education, a collaboration of businesses, colleges and universities, community organizations and parents in support of quality education throughout the Cambridge public school system. Additionally, he continues to represent MIT in educational projects sponsored by the New England Board of Higher Education, the Quality Education for Minorities Project, based in Washington, and the NSF/Northeastern University Regional Science Center proposed for Boston.

Assistant Dean Margaret D. Tyler was chosen at year's end to serve as the Dean in Residence at the Washington office of the Council of Graduate Schools. Dean Tyler will be on leave for ten months in the coming year to serve in this position where she will have an opportunity to participate in a variety of activities including minority recruiting at the national level.

OTHER ISSUES & ACTIVITIES

During its deliberations, the Weinberg committee, which was referred to earlier in this report, determined that it was appropriate to consider tuition schemes in which doctoral students who have completed all requirements except the dissertation would be charged a greatly reduced tuition. Such all-but-dissertation (ABD) tuition schemes are in effect at many universities and were deemed appropriate for consideration at this particular time when other changes in tuition policy were about to be imposed by government action. The timing was also appropriate because in its deliberations the Weinberg committee focused on schemes in which some subsidization of the tuition of graduate RAs would occur. Finally, the Graduate Student Council (GSC) determined that adoption of an ABD tuition policy was a cause for which they were prepared to lobby vigorously. However, despite all of these motivating factors, the costs of adopting a broadly applicable ABD tuition were found to be excessive, and no action on this concept seems likely in the near future. Discussion then turned to more limited versions of the ABD mechanism (e.g., restricting its use to specific departments), and to modifications of our current non-resident doctoral dissertation status which is effectively a restricted form of ABD status. The GSC formally endorsed a liberalization of the tuition policy associated with non-resident status; discussion of that proposal was still under way at year's end by the Education Committee of the Academic Council.

GRADUATE SCHOOL STATISTICS

Important statistics concerning the Graduate School are presented in Tables I-V and Figures I-III, which follow. The format and content of these figures and tables are essentially identical to those which were presented last year.

The enrollment figures in Table I show no major changes from last year. The total graduate student enrollment grew just over 1% but still remains just below its peak in 1987. There was a small increase in the number and percentage of women students but a decrease in the number and percentage of minority students. The increase in number of women students to 22% continues a trend which became apparent last year, when enrollment rose to 21.7% after being fixed around 20% for several years (Table V and Figure I). The downturn in minority enrollments is largely attributable to decreased enrollments in Urban Studies and Planning (31 in Fall 1990 to 23 in Fall 1991), which has experienced significant and ongoing problems in finding adequate funding to attract minority students in numbers comparable to past years. The number of international students continued to rise but the increase was smaller than that in the previous two years. (Table V and Figure II).

The data in Table II include tuition amounts for some students in the Joint Program with the Woods Hole Oceanographic Institute which were not included in previous reports. The data indicate a 14.8% increase in total tuition support, but, when adjusted by removal of the WHOI tuitions, represent only a 6.6% increase. The data also show a 6.3% increase in total stipend support. These increases are consistent with the growth in MIT's tuition and the small increase in graduate student population.

The number of graduate applications for admission continue to grow, as reflected in the figures in Table III. 10,062 applications were received in the Fall of 1991, an increase of 619 applications (6.6%) over the previous year. These increases were distributed over almost all MIT departments. There was little change in either the ratio of students admitted/applied or the number registered/admitted.

The data for degrees awarded, which appear in Table IV, show a modest increase in the number of doctoral and Engineer's degrees awarded, and little change in the number of Master's degrees.

FRANK E. PERKINS

	FOREIGN	WOMEN	MINORITY	NEW	NON-RESIDENT	TOTAL
SCHOOL OF ARCHITECTURE & PLANNING	**120**	**164**	**38**	**155**	**35**	**442**
Architecture	74	88	15	91	18	279
Urban Studies & Planning	46	76	23	64	17	163
SCHOOL OF ENGINEERING	**788**	**375**	**62**	**498**	**26**	**2242**
Aeronautics & Astronautics	73	19	5	59	2	206
Chemical Engineering	72	42	10	34	1	201
Civil Engineering	152	55	4	88	8	293
Electrical Eng & Computer Science	146	127	26	135	7	674
Materials Science & Engineering	67	52	5	33	2	185
Mechanical Engineering	153	48	10	95	1	404
Nuclear Engineering	61	12	2	15	2	126
Ocean Engineering	64	20	0	39	3	153
SCHOOL OF HUMANITIES & SOCIAL SCIENCES	**126**	**112**	**7**	**76**	**57**	**380**
Economics	50	34	3	30	7	141
Linguistics & Philosophy	32	15	0	14	4	59
Political Science	41	56	4	27	46	163
Science, Technology & Society	3	7	0	5	0	17
SCHOOL OF MANAGEMENT	**271**	**133**	**24**	**324**	**8**	**667**
SCHOOL OF SCIENCE	**333**	**271**	**22**	**184**	**23**	**1090**
Applied Biological Sciences	3	6	0	0	2	15
Biology	30	87	0	33	4	208
Chemistry	57	72	5	44	9	254
Earth, Atmospheric & Planetary Sci	66	44	0	37	1	166
Mathematics	61	18	0	26	5	119
Physics	106	31	13	40	2	301
Toxicology	10	13	4	4	0	27
WHITAKER COLLEGE	**15**	**11**	**2**	**13**	**0**	**55**
Brain & Cognitive Sciences	15	11	2	13	0	55
Health Policy & Management	0	0	0	0	0	0
HEALTH SCIENCES & TECHNOLOGY	**21**	**26**	**0**	**22**	**0**	**91**
TOTAL GRADUATE ENROLLMENT	**1674**	**1092**	**155**	**1272**	**149**	**4967**
CATEGORY AS % OF TOTAL	**33.7%**	**22.0%**	**3.1%**	**25.6%**	**3.0%**	

"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 1991

CATEGORY OF SUPPORT	NUMBER OF STUDENTS (ACTUAL)	NUMBER OF STUDENTS (EFS)	TUITION FALL TERM	TUITION SPRING TERM	STIPEND FALL TERM	STIPEND SPRING TERM	TOTAL ACADEMIC YEAR SUPPORT
Research Assistantships	2,695	1,994	16,925	16,767	10,070	10,059	53,821
Teaching Assistantships	743	431	3,772	3,511	2,346	2,205	11,834
Graduate Instructorships	5	4	35	25	120	124	304
Federal Fellowships/Traineeships	353	222	1,892	1,852	319	318	4,381
MIT Endowed Support (Dept'l)	168	72	692	522	304	237	1,755
MIT Endowed Support (ODGS)	67	55	471	462	142	126	1,201
MIT General Support	533	213	1,853	1,755	934	779	5,321
Industrial Fellowships	673	377	3,220	3,150	2,551	2,560	11,481
Foundation Fellowships	233	159	1,371	1,323	762	715	4,171
Billed by MIT to Outside Sponsors*	N/A	508	4,322	4,261	0	0	8,583
TOTAL IDENTIFIED SUPPORT	**4152****	**4,034**	**34,553**	**33,628**	**17,548**	**17,123**	**102,852**

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 tuition support by the academic year tuition of $16,900 per student.

* includes students enrolled in MIT/WHOI Joint Program

** does not equal total of above numbers because some students receive funding from more than one source

TABLE II: SOURCES AND AMOUNTS OF GRADUATE STUDENT SUPPORT, 1991-92 ACADEMIC YEAR

(DOLLAR AMOUNTS REPRESENTED IN THOUSANDS)

	NUMBER OF APPLICANTS	NUMBER ADMITTED	RATIO ADMIT/APPL	# PLANNING TO REGISTER	RATIO REG/ADMIT
SCHOOL OF ARCHITECTURE & PLANNING	**1021**	**290**	**0.28**	**168**	**0.58**
Architecture	638	152	0.24	98	0.64
Urban Studies & Planning	312	124	0.40	69	0.56
Real Estate Development*	71	14		1	
SCHOOL OF ENGINEERING	**3693**	**1042**	**0.28**	**449**	**0.43**
Aeronautics & Astronautics	239	118	0.49	59	0.50
Chemical Engineering	225	81	0.36	34	0.42
Civil Engineering	386	205	0.53	92	0.45
Electrical Eng & Computer Science	1695	269	0.16	105	0.39
Materials Science & Engineering	229	56	0.24	29	0.52
Mechanical Engineering	616	196	0.32	87	0.44
Nuclear Engineering	102	47	0.46	17	0.36
Ocean Engineering	108	70	0.65	26	0.37
Technology & Policy*	82				
Transportation Studies*	11				
SCHOOL OF HUMANITIES & SOCIAL SCIENCES	**948**	**184**	**0.19**	**78**	**0.42**
Economics	481	64	0.13	31	0.48
Linguistics & Philosophy	176	40	0.23	16	0.40
Political Science	233	75	0.32	27	0.36
Science, Technology & Society	58	5	0.09	4	0.80
SCHOOL OF MANAGEMENT	**2221**	**382**	**0.17**	**269**	**0.70**
Master's Programs	1728	336	0.19	244	0.73
Doctoral Program	430	27	0.06	19	0.70
Operations Research*	63	19		6	
SCHOOL OF SCIENCE	**1921**	**461**	**0.24**	**178**	**0.39**
Biology	438	84	0.19	32	0.38
Chemistry	416	146	0.35	45	0.31
Earth, Atmospheric & Planetary Sciences	159	54	0.34	32	0.59
Mathematics	299	51	0.17	28	0.55
Physics	609	126	0.21	41	0.33
WHITAKER COLLEGE	**228**	**34**	**0.15**	**16**	**0.47**
Brain & Cognitive Sciences	195	26	0.13	13	0.50
Toxicology	33	8	0.24	3	0.38
HEALTH SCIENCES & TECHNOLOGY	**30**	**14**	**0.47**	**14**	**1.00**
INSTITUTE TOTALS	**10062**	**2407**	**0.24**	**1172**	**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 1991

	NUMBER OF INDICATED DEGREES				
	Ph.D.	Sc.D.	Engineers	Masters	Total
SCHOOL OF ARCHITECTURE & PLANNING	**18**	**-**	**-**	**151**	**169**
Architecture	10	-	-	88	98
Urban Studies & Planning	8	-	-	63	71
SCHOOL OF ENGINEERING	**213**	**26**	**31**	**575**	**845**
Aeronautics & Astronautics	24	2	0	65	91
Chemical Engineering	28	4	0	29	61
Civil Engineering	22	7	3	79	111
Electrical Eng & Computer Science	61	1	14	167	243
Materials Science & Engineering	24	4	0	31	59
Mechanical Engineering	27	4	0	146	177
Nuclear Engineering	20	0	3	27	50
Ocean Engineering	7	4	11	31	53
SCHOOL OF HUMANITIES & SOCIAL SCIENCES	**49**	**-**	**-**	**17**	**66**
Economics	23	-	-	2	25
Linguistics & Philosophy	13	-	-	2	15
Political Science	13	-	-	13	26
Science, Technology & Society	0	-	-	0	0
SCHOOL OF MANAGEMENT	**29**	**-**	**-**	**358**	**387**
SCHOOL OF SCIENCE	**160**	**2**	**-**	**29**	**191**
Applied Biological Sciences	9	1	-	1	11
Biology	23	0	-	1	24
Chemistry	44	0	-	4	48
Earth, Atmospheric & Planetary Sciences	22	1	-	10	33
Mathematics	25	0	-	2	27
Physics	37	0	-	11	48
WHITAKER COLLEGE	**12**	**-**	**-**	**3**	**15**
Brain & Cognitive Sciences	9	-	-	0	9
Toxicology	3	-	-	3	6
Health, Policy & Management	0	-	-	0	0
HEALTH SCIENCES & TECHNOLOGY	**5**	**-**	**-**	**1**	**6**
TOTAL GRADUATE DEGREES	**486**	**28**	**31**	**1134**	**1679**

These figures include 29 graduate degrees awarded through the MIT-Woods Hole Oceanographic Institution Joint Program as follows: 16 PhD's (5 in Engineering, 11 in Science), 1 ScD (in Engineering), 2 Engineer's Degrees, and 10 Master's Degrees (6 in Engineering, 4 in Science).

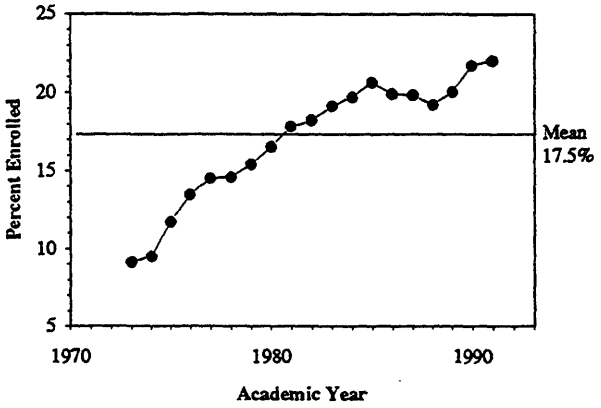
TABLE IV: GRADUATE DEGREES AWARDED IN ACADEMIC YEAR 1991-92

ACADEMIC YEAR	NUMBER OF WOMEN	PERCENT WOMEN	NUMBER OF FOREIGN NAT.	PERCENT FOREIGN NAT.	NUMBER OF MINORITIES	PERCENT MINORITIES	TOTAL ENROLLMENT
1973	304	9.1%	927	27.9%	108	3.2%	3,328
1974	318	9.5%	954	28.4%	121	3.6%	3,358
1975	405	11.7%	970	28.0%	151	4.4%	3,468
1976	487	13.5%	1,037	28.8%	155	4.3%	3,603
1977	546	14.5%	1,059	28.1%	178	4.7%	3,774
1978	559	14.6%	1,151	30.1%	157	4.1%	3,824
1979	606	15.4%	1,145	29.0%	147	3.7%	3,944
1980	684	16.5%	1,219	29.4%	150	3.6%	4,146
1981	779	17.8%	1,283	29.3%	174	4.0%	4,384
1982	828	18.2%	1,347	29.7%	140	3.1%	4,541
1983	856	19.1%	1,418	31.6%	145	3.2%	4,489
1984	914	19.7%	1,439	31.1%	143	3.1%	4,631
1985	981	20.6%	1,449	30.5%	141	3.0%	4,757
1986	981	19.9%	1,658	33.7%	139	2.8%	4,920
1987	987	19.8%	1,497	30.1%	144	2.9%	4,979
1988	929	19.2%	1,441	29.8%	154	3.2%	4,832
1989	963	20.0%	1,498	31.1%	159	3.3%	4,822
1990	1,064	21.7%	1,628	33.2%	168	3.4%	4,909
1991	1,092	22.0%	1,674	33.7%	155	3.1%	4,967
TOTALS	**14,283**	**17.5%**	**24,794**	**30.4%**	**2,829**	**3.5%**	**81,676**

TABLE V: WOMEN, FOREIGN NATIONAL AND MINORITY ENROLLMENT, AY1973 TO AY1991

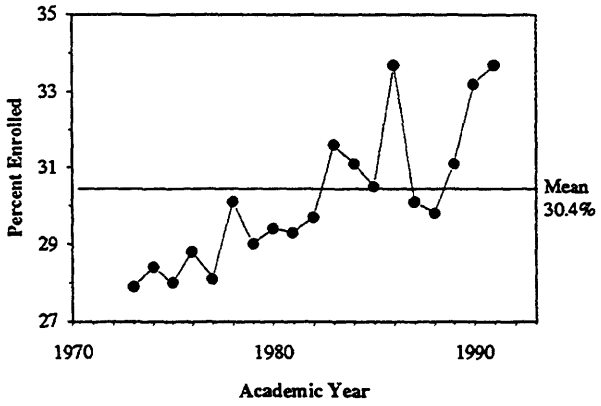
ENROLLMENT OF GRADUATE WOMEN
AY 1973 - AY 1991

FIG. I



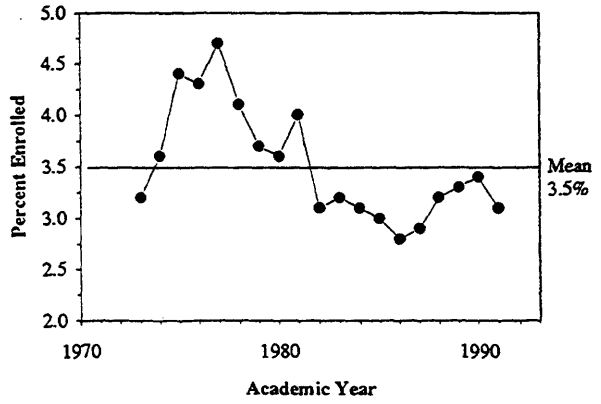
INTERNATIONAL GRADUATE ENROLLMENT
AY 1973 - AY 1991

FIG. II



MINORITY GRADUATE ENROLLMENT
AY 1973 - AY 1991

FIG. III



Lowell Institute School

BACKGROUND

The Lowell Institute School (LIS) was established at MIT in 1903 to provide evening instruction in technical subjects for residents of the Boston area. Today the School continues this tradition by offering subjects in the areas of modern technology which are not readily available at other evening institutions. Entry-level courses require an adequate high school preparation, and the more advanced instruction is geared to the practicing technician who has an Associate degree or equivalent experience.

Programs of study range from single subjects designed to broaden job skill levels to comprehensive study of new technological areas in preparation for employment in a new field. There is a strong emphasis on practical aspects and development of careful experimental technique combined with sufficient theory to provide an adequate foundation of understanding. Certificates are awarded to those who satisfactorily complete a course. In addition, students who complete a program of courses may earn a Certificate in Electronics Technology, Drafting Technology, or Computer Technology.

CURRICULUM

During 1991-92, LIS enjoyed a 21 percent increase in enrollment, due in part to the new, professionally designed *Catalog*. The School offered 35 different courses in analog and digital electronics, microprocessors, computer literacy, computer programming in BASIC and C, drafting, geometric dimensioning and tolerancing, computer aided drafting and circuit board design, alarm technology, and a review course to prepare students for the Engineer-In-Training examination. In addition to refresher courses in mathematics, elementary calculus was included in the curriculum.

New courses were introduced in elementary computer skills, C++ programming, computer aided drafting for architects and engineers, computer integrated manufacturing, and key technologies in optoelectronics.

A seven-week summer program meeting twice weekly was continued this year to respond to the heavy demand for computer instruction. One hundred forty-seven students enrolled in courses in AutoCAD, computer literacy, the IBM disk operating system, and programming in the BASIC, C, and X Window environments.

AFFIRMATIVE ACTION

LIS admitted a total of 1,127 students to its courses in 1991-92. Of those enrolled, 83 percent successfully fulfilled the certificate requirements. Among those who completed courses were 108 MIT employees and three MIT students. Four students earned the Certificate in Electronics Technology, four students earned the Certificate in Drafting Technology, and one student earned the new Certificate in Computer Technology. Twenty-seven percent of the students were women (up five percent from last year) desiring to enter or to improve their positions in technical fields. The instructing staff of 31 includes two blacks, one Asian, and two women.

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 Office

Special Summer Programs

The Summer Session Office administers an extensive series of one- and two-week special programs for professional men and women who wish to keep pace with developments in their fields. This activity has prospered each summer since its initiation in 1950. Current information on subjects and registrations is as follows:

Summer 1990: 1789 registrations in 78 special programs by 1755 individuals
Summer 1991: 1630 registrations in 83 special programs by 1594 individuals

Foreign students comprised approximately 7 percent of this registration.

Regular Students

Graduate students comprise 86 percent of the student body during the summer. The 1991 registration of 3159 students was an increase from 3136 in 1990.

Joint Program in Oceanography/Applied Ocean Science and Engineering

NAME CHANGE

Effective December 1991, the name of the Joint Program was changed to "Joint Program in Oceanography/Applied Ocean Science and Engineering" to better reflect the overall composition of the faculty and students.

MIT/WOODS HOLE UROP PROGRAM

Begun in June, 1991, the MIT UROP program was expanded to include opportunities for research at Woods Hole Oceanographic Institution (WHOI). MIT undergraduates pursued a wide variety of topics related to ocean research while working with WHOI scientists. The program was deemed a great success by both students and investigators.

OCEANOGRAPHER OF THE NAVY SITE VISIT

On May 1 the Oceanographer of the Navy, Geoffrey Chesbrough, visited MIT to review the curriculum of the naval officers in the Joint Program and discuss the Navy's ongoing involvement. Participants included senior officials from the Naval Postgraduate School in Monterey, and faculty from the Departments of Ocean Engineering at MIT and Applied Ocean Physics and Engineering at WHOI.

Since 1984, the year of inception, 42 Naval officers have enrolled in the Joint Program, principally to earn master's and/or engineer's degrees in oceanographic engineering. Many of these graduates have gone on to pursue distinguished careers in both public office and private industry.

No significant changes in the Program were proposed as a result of the review.

ADMISSIONS STATISTICS

Enrollment in the Joint Program increased by 10% - from 125 in 1990-91 to 138 for 1991-92. The projected enrollment estimate for September, 1992 is 156 students, with 18 in Chemical Oceanography, 25 in Marine Geology and Geophysics, 31 in Biological Oceanography, 41 in Applied Ocean Science and Engineering, and 41 in Physical Oceanography.

There were 177 applicants to the Joint Program for 1992-93, a 12 percent increase over last year. Fifty students were admitted to the program; of these, 37 (74%) accepted our offer of admission. Women comprise 32 percent of the entering class. Of the incoming students, all but three will be doctoral candidates, and eight are minorities.

JOINT PROGRAM GRADUATES

Overall, the Joint Program graduated 22 students in 1991-92; of these, 14 received the doctorate, seven received the master's degree, and one received the engineer's degree. The breakdown by discipline is as follows: Chemical Oceanography (three); Biological Oceanography (one); Marine Geology and Geophysics (three); Physical Oceanography (four); and Applied Ocean Science and Engineering (eleven).

SALLIE W. CHISHOLM

VICE PRESIDENT AND DEAN FOR RESEARCH

Whitaker College of Health Sciences and Technology

The Whitaker College is an interdisciplinary academic and research entity at MIT, established in 1977 to bring together the biological, engineering, and physical sciences to improve human health. Research and education in the College take place in several interdisciplinary programs, and three departments; the Department of Brain and Cognitive Sciences, the Division of Toxicology and the Center for Environmental Health Sciences.

I am pleased to report here on the events and new initiatives of programs that operate within the College core. The activities of the Departments and Centers are reported separately.

PROGRAMS IN BIOENGINEERING

Programs in bioengineering focus on (1) biomedical imaging and computer simulation of radiation transport, and (2) medicinal chemistry and drug delivery systems.

BIOLOGICAL IMAGING AND COMPUTATION

Research in imaging and computer simulation takes place in the Whitaker College Biomedical Imaging and Computation Laboratory (WCBICL). In addition to providing a site for the primary faculty associated with this effort, the goal of the laboratory is to encourage faculty, research staff, and students in relevant departments to collaborate on basic research in imaging technologies and display methods, and simulation of radiation transport.

The resources of the laboratory currently include eight SUN Microsystems workstations, two Silicon Graphics workstations, and two Macintosh computers. All are directly connected to the MIT Campus Network. Currently there are more than 75 registered users of the laboratory.

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 on 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.

Professor Jacqueline Yanch of the Department of Nuclear Engineering conducts research that has created a new direction of inquiry which operates in parallel to efforts in medical imaging. The goal is the understanding and improvement of radiation therapy using the tool of computer simulation. This research involves intensive computational effort which is well met by the lab's workstations. Computational activities deal with Monte Carlo calculation of radiation penetration and dosimetry for neutron capture therapy, the simulation of performance of imaging systems, and the improvement in image quality by techniques such as simulated annealing.

The WCBICL continues to play an increasingly important role in education, particularly with respect to the Department of Nuclear Engineering and the Harvard-MIT Division of Health Sciences and Technology Medical Engineering and Medical Physics (MEMP) doctoral programs. Many of the students in these programs use the facility for their research and the lab is also used for teaching and experimentation in both HST and NED. The laboratory projects are designed to provide practical experience in processing physiological data with examples from neurophysiology, cardiology, and two dimensional image analysis. Particularly noteworthy this year was a mini-course entitled "Quantitative Cardiac Imaging" presented by an invited lecturer, Dr. Johan C. Reiber, Director of the Laboratory for Clinical and Experimental Image Processing at University Hospital, the Netherlands. I am pleased to report that the lectures were well received with attendance and enthusiasm from MIT as well as related imaging centers in the Boston area.

MEDICINAL CHEMISTRY AND CONTROLLED DRUG DELIVERY SYSTEM

Professor Langer holds a secondary appointment in Whitaker College and a primary appointment in the Department of Chemical Engineering.

Research activities in Professor Robert Langer's laboratory continue in four major areas: (1) drug delivery systems; (2) cell delivery systems; (3) drug removal systems using immobilized enzymes; and (4) studies on angiogenesis inhibition.

Some of his recent advances include the following: A drug delivery system using biodegradable polymers and developed by Professor Langer's group is now being used in the treatment of over two hundred patients with brain tumors. The initial results indicate that life span is significantly increased when compared to conventional therapies. In the cell delivery system area, significant progress has been made by using polymers as novel carriers for delivering liver cells and cartilage cells. The hope is that this research could lead to a new approach in organ transplantation. In the area of drug removal systems, important advances have been made in developing an immobilized, low-density lipoprotein enzyme (LDL) cholesterol removal reactor. Studies *in vivo* and *in vitro* have shown that a novel immobilized enzyme can remove cholesterol seventeen times faster than normal. Finally, Professor Langer and his laboratory have purified and sequenced a substance from cartilage that causes inhibition of neovascularization.

In addition to teaching both semesters, Professor Langer and his colleagues presented a one-week summer course in Controlled Drug Delivery Systems. This year, he supervised sixteen graduate students who represented the departments of Chemical Engineering, Chemistry, Material Sciences and Engineering, and the Division of Health Sciences and Technology. In addition, his laboratory includes ten undergraduates, eleven postdoctorals, two visiting scientists, and eight research staff.

FACULTY AND STAFF

Professor Robert Langer was elected to both the National Academy of Engineering and the National Academy of Sciences. He has been the recipient of several awards this year including the American Chemical Society Award for Applied Polymer Science and the Charles M. A. Shine Award in Materials Science and Engineering from the American Institute of Chemical and Biochemical Engineering.

Professor Jacquelyn Yanch received a General Electric Faculty for the Future Career Development Award in 1992. This was one of two such awards made to the Institute. Professor Yanch has been named the recipient of the Keck Foundation Professorship in Biomedical Engineering in the Whitaker College, effective July 1, 1992, after having held the Class of 1958 Assistant Professorship Chair since 1989. Professor Yanch will become the new Director of the Biological Imaging and Computation Laboratory effective July 1, 1992.

J. DAVID LITSTER

Research in the Department of Brain and Cognitive Science integrates diverse approaches to the understanding of brain functions and provides an opportunity for comprehensive and multidisciplinary training of new scientists within the department and through collaborative efforts with other departments and laboratories.

In the Department of Brain and Cognitive Sciences, there are five primary areas of research: neurobiology, computational neuroscience, systems neuroscience, and cognitive science.

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 molecular basis of behavior, research efforts using the **Drosophila** have identified mutations that affect programmed cell death and the production of neurons from neuronal precursor cells.

With respect to neurochemistry and neurotransmitters, two potentially major discoveries concerning the causes and mechanisms of Alzheimer's Disease have been made this year. The first was the demonstration that the turnovers of the major phospholipid constituents in brain membranes are abnormally accelerated, causing absolute brain levels of these compounds to fall. The second was the demonstration that the normal mechanism by which brain cells destroy a protein which, when metabolized abnormally, can yield fragments that form amyloid, depends on stimulation by acetylcholine. Hence, the general decrease in brain acetylcholine levels characteristic of Alzheimer's Disease may be a cause of the formation of the abnormal amyloid protein.

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.

Recently new phenomena involving specific inhibitory influences arising from glial cells upon retinal axon growth have been described.

New tracer molecules to map the earliest stages of sensory map formation in the neural pathway from the facial skin to the neocortex have been applied and a surprisingly early establishment of the axial orientation of the map was discovered. Upon this cruder map is superimposed a detailed patterning due to influences of the sensory periphery.

In the area of motor control, progress has been made in understanding the mechanisms and circuitry underlying the transformation of motor plans into motor commands. A central feature of this transformation is a coarse map of limb postures in the premotor areas of the spinal cord.

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. Special efforts have resulted in refining a theory to explain how the brain, or parts of it, may work. In particular, work has been done on how the visual system may learn to recognize 3D objects and how it may learn to perform specific tasks, such as hyperacuity.

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, reasoning, memory, and human conceptual development. This work has been expanded to include studies of the genetic and neural underpinnings of grammar.

There were three noteworthy achievements during the past year: a. publication of a definitive quantitative study of children's speech errors and their significance; b. demonstration that a syndrome of developmental language impairment appears to be caused by a single defective dominant gene; and c. replication of the basic findings with speakers of German, a language with very different statistical properties from English.

McDonnell-Pew Center for Cognitive Neuroscience
Financial support from the McDonnell Pew Foundation has enables us to establish the McDonnell-Pew Center. The center awarded five predoctoral and six postdoctoral fellowships in its second year. Each of the recipients has made advances in his research and submitted several papers for publication. Three of our current and former recipients have accepted tenure track positions at prestigious universities. In addition to the regular series of seven seminars initiated last year and repeated this spring, a second weekly series focusing on studies of human cognition using the technique of Positron Emission Tomography (PET) was established. Students organized two journal clubs: one covers the area of systems neuroscience and its relevance to issues in cognitive neuroscience, and the other focuses on language viewed from both cognitive and biological perspectives. Students and Postdoctoral Fellows from MIT and other area institutions have been participating.

Lucille P. Markey Program in Neurobiology
This year, financial support from the Markey Charitable Trust enabled us to expand the Microscopy/Imaging facility by upgrading the services. A motorized stage was purchased for the confocal microscope, thereby enabling us to image one area of a slide, move automatically to another area, image that area and then re-image the first area. This allows time-lapse confocal studies of live samples by watching several areas in parallel.

The Silicon Graphics workstation now has additional memory and storage thus allowing quicker 3-D reconstruction renderings and larger images. Peripherals and enhanced software have been added to the time-lapse video microscopy giving more flexibility in collecting and storing images.
The award from the Markey foundation has also allowed the Department to

grant a third postdoctoral fellowship, support four graduate students and sponsor a retreat on Cape Cod in June to further develop the collaboration and exchange of information on the progress of their research.

EDUCATION

Postdoctoral

Postdoctoral applications continue to increase, fueled by the reputation of the Department for outstanding research. Fellowships are supported by a variety of sponsors, both federal and private.

Graduate

We continue to attract a strong pool of applicants to the graduate program and will have an entering class in 1992 of eleven students. Two of these were admitted to a new joint program with the Dept. of Linguistics and Philosophy in psycholinguistics and linguistics, funded by a research training grant from the National Science Foundation. Departmental graduates continue to be successful in obtaining postdoctoral positions.

We are happy to report that two departmental training grants, one from NIGMS entitled Integrative Neuronal Systems, and one from NIMH entitled Development of Cognition, were approved for five additional years of funding.

Undergraduate

Our undergraduate program has been reorganized. The areas related to the undergraduate major, such as the Program in Psychology, the minor in psychology and the concentration in psychology, as well as UROP advising have been centralized and are now under the supervision of the Academic Officer. New courses have been offered--Cognitive Neuroscience and Computation, Perception and Motor Control--as well as a new area, Brain and Behavior. In addition, this department had the largest percentage of faculty participation in IAP in the Institute.

AFFIRMATIVE ACTION

The Department has taken several steps to enhance the recruiting of underrepresented minorities and women for faculty and staff positions. We have appointed two faculty members to take an active role in faculty searches, and registered with MOLIS, the electronic minority information service, in addition to increasing markedly the number of individuals and organizations notified of openings. Our minority recruiter attended two symposia in Washington and spoke with a few African Americans who hold Ph.D.s in appropriate fields, but was not able to convince them to move to the Boston area. He has also been in touch with Deans of Minority Affairs of various institutions so that he can be kept apprised of promising undergraduates. Efforts to recruit at the APA were unsuccessful as the minorities with Ph.D.s had specialized in clinical or social psychology.

OTHER ACTIVITIES

The Department has continued to offer very popular lunchtime seminars featuring speakers of national and international renown. These seminars have consistently been popular and well received.

FACULTY AWARDS AND ACTIVITIES

Individual members of the faculty have been extremely productive and

have received recognition by the Institute and outside foundations.

Edward Adelson - Rank Prize in Opto-electronics
Adolph Lomb Medal, Optical Society of America
Outstanding Achievement Award, RCA Laboratories
Marquis Award, University of Michigan

Christopher Atkeson - Graduate Student Council Departmental Teaching Award in Course 9

Robert Berwick - Vinton Hayes/IBM Fellow 1993-96

Emilio Bizzi - Hermann von Helmholtz Award for Excellence in Neuroscience 1992

Michael Jordan - Class of 1947 Career Development Chair
NSF/Presidential Young Investigators Award
American Control conference Best Presentation Award

Steven Pinker - German-American Collaborative Research Award from the American Council of Learned Societies and the Deutscher Akademischer Austauschdienst

Richard Wurtman - Distinguished Lecturer in Neuroscience, Louisiana State University School of Medicine

EMILIO BIZZI, M.D.
Chairman

INTRODUCTION

The Division of Toxicology is an administrative and academic unit within the Whitaker College of Health Sciences and Technology. The major educational activity of the Division is the operation of a graduate degree program leading to SM/PhD degrees in toxicology. The teaching as well as research programs of the Division emphasize understanding mechanisms through which chemical and physical agents in the environment induce toxicity and pathogenesis, with the ultimate goal of elucidating the role of environmental agents in the etiology of genetic and genetically-linked diseases, especially cancers, in humans. The program requires strong undergraduate backgrounds in basic science, especially chemistry and biology. Emphasis is placed on advanced courses in biochemistry, molecular biology and genetics, carcinogenesis and toxicology, together with the development of research approaches to current problems in environmental health sciences, utilizing the methods and logic of biochemistry and molecular biology.

The major long range goals of the research programs of the faculty members in the Division of Toxicology are to elucidate at cellular and molecular levels the mechanisms of action of toxic agents in order to facilitate development of preventive or therapeutic measures to eliminate or minimize human health risks arising from exposure to environmental chemicals. Information resulting from elucidation of mechanisms of action of toxic chemicals is of critical importance in extrapolating data from experimental systems to man in risk assessment and in the development of regulatory policy to minimize risk.

These goals are approached through a number of avenues of experimentation. Some projects concern the identification of sources and the development of assay methods for detection of potentially hazardous chemicals that are generated through anthropogenic or natural pathways. A major area of current research emphasis is the development and application of methodologies for direct measurement, in human subjects, of exposures to hazardous environmental chemicals and for detection of certain kinds of deleterious effects resulting from such exposures. Several such methods have been developed and shown to be capable of detecting exposures and effects at ordinary ambient levels of a variety of ubiquitous environmental carcinogens and mutagens and are therefore capable of providing quantitative information about the associated risks. These methods are currently being applied in epidemiological studies, in which they greatly enhance the power to detect individuals at high risk by virtue of exposure or physiologic condition and thereby improve the development of control strategies.

FACULTY

Faculty members whose primary academic affiliations are in the Division include Professors Peter C. Dedon, John M. Essigmann, Steven R. Tannenbaum, William G. Thilly, Gerald N. Wogan, and Helmut Zarbl. A final candidate has been identified for a new faculty position as Assistant Professor of Toxicology, and a formal offer of appointment has been extended. If accepted, the appointment will become effective January 1, 1993. Professor James G. Fox, director of the Division of Comparative Medicine also holds a secondary appointment in the Division of Toxicology. Professors Essigmann, Tannenbaum and Wogan hold joint appointments in the Department of Chemistry, and Professor Thilly in the Department of Civil Engineering.

EDUCATIONAL PROGRAM

The major educational activity of the Division is the operation of a degree program that offers graduate level training leading to doctoral or master's degrees in Toxicology. The curriculum of the doctoral program is designed to provide rigorous training in the basic sciences, with particular emphasis on chemistry, biochemistry, molecular biology, genetics and toxicology. The content as well as structure of the curriculum is reviewed regularly by the faculty, and modifications are introduced as they are deemed desirable. All members of the faculty participated in a one-day retreat in June, 1991, at which the content of each required course was reviewed in detail, in the context of the entire curriculum,

including elective courses. Substantial revisions identified by that review were implemented during the 1991-92 academic year. Students receive preparation for academic, industrial or governmental careers involving the application of modern methods of chemical, molecular biological and genetic analysis to research related to evaluation of risks associated with chemical exposures. The scope of both educational and research programs encompasses subject matter appropriate to chemical, biotechnology, pharmaceutical, and food industries, as well as to governmental regulatory and research agencies.

Faculty members of the Division of Toxicology are drawn from a wide range of disciplines, and as noted above, some hold joint appointments in the Departments of Chemistry, Civil Engineering and Comparative Medicine. The members of the Division also form the nucleus of the MIT Center for Environmental Health Sciences, as discussed below.

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 ordinarily involves a committment of four to 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 involving numerous participants at various levels. Many interactions take place between members of the Division and faculty of departments within the School of Science and also across School lines, in particular with the School of Engineering. A very extensive research collaboration is that involved in the NIEHS Environmental Health Sciences Center. The Center was established at MIT in 1978 with funding provided by the National Institute of Environmental Health Sciences (NIEHS), and has the objective of conducting a comprehensive program of research on the health effects of a variety of environmental chemical exposures. 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 first of these programs is designed 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. The scope of the program has recently been expanded by addition of projects with faculty members of the Departments of Chemical and Civil Engineering.

HONORS AND AWARDS

The following honors and awards were accorded to faculty and students of the Division during the current academic year.

Prof. Helmut Zarbl was promoted to the rank of Associate Professor.

Ms. Hilary Coller was the recipient of the Martin Fellowship in Environmental Affairs.

Ms. Xiaoquan Zhai was one of five MIT students awarded a Sir Run Run Shaw Graduate Fellowship.

Znaty Awards for Graduate Research were awarded to Ms. Rita S. Cha and Mr. Choon-Joo Kho in recognition of their doctoral thesis research with Profs. Zarbl and Thilly, respectively.

Mr. Donald Brunson and Ms. LaCreis Kidd received fellowships from the Minorities Access to Research Careers (MARC) program of the NIH, and Ms. Deirdre Lawrence has been supported by a Ford Foundation Fellowship.

Mr. Esequiel Barrera, a first-year graduate student, has been selected as a recipient of a five-year National Research Service Award for Minority Students.

GERALD N. WOGAN

The Center is a collaborative research and educational organization with two goals:

One: Find out what causes genetic damage in people.
Two: Get rid of it.

The cross - disciplinary research organization necessary to make progress toward these goals is a continuing challenge. We know that people suffer from myriad inherited diseases and cancer which require genetic changes. However, no one knows what the main causes of human genetic damage are. We developed human cell assays in the Center that have shown powerful human cell mutagens can be found in food, air and water. We don't know if any of those powerful environmental mutagens have caused any human disease.

The main problem is that genetic damage also happens when human cells divide in the absence of environmental chemicals or radiation. DNA replication systems make mistakes. Our own bodies' metabolism produces plenty of reactive compounds which could be the main culprits. The concentrations of environmental chemicals to which we are exposed are quite low. It is possible that most human genetic damage would occur in a pristine environment.

Thus Center toxicologists and analytical chemists have spent most of the research funds in devising ways to make measurements in the human body capable of distinguishing among these possibilities. Professor Klaus Biemann (Chemistry) is devising a mass spectrometric methodology capable of measuring chemical reaction products of previously unidentified chemicals in human blood proteins. Professor Steven Tannenbaum (Toxicology) has already devised means to measure the aromatic amine and polycyclic aromatic hydrocarbons adducted to blood proteins. His laboratory has completed several field studies demonstrating the value of the new technology. This work was made possible by a collaboration with Dr. Ramachandra Dasari (Physics) bringing laser induced fluorescence spectrometry to bear on the analytical problem. Professor Gerald Wogan (Toxicology) has used measurements of DNA adducts in urine and tissue specimens to accurately measure exposure to the ubiquitous carcinogenic mold toxins. He and his collaborators have demonstrated a marked interaction between dietary mold toxins and hepatitis B infection in causing death by liver cancer in China. Professor William Thilly (Toxicology) has devised means to observe the set or spectrum of mutations in human cells which he has argued will yield the genetic fingerprint of an organ's primary cause of mutation. Professor Helmut Zarbl (Toxicology) has developed a simple, rapid method that for the first time has the sensitivity to measure mutations required for human cancer directly in tissues or blood samples of non-symptomatic individuals. At the theoretical level, a new paradigm relating mutation rates and inherited human mutations to the age dependence of cancer deaths in humans has been developed within the Center.

Plans for the coming year include beginning the study of the kinds of mutations found in the bodies (blood cells, livers, lungs) of persons of average lifestyles and of persons with particularly marked environmental chemical exposure. The coordination of multiple approaches to direct analysis of chemicals and patterns of genetic change in humans is one of the most important reasons for the Center's existence.

In the past few months we have completed a useful reorganization of CEHS environmental engineering and toxicology groups into two major integrated entities, the Air Quality and Water Quality Programs.

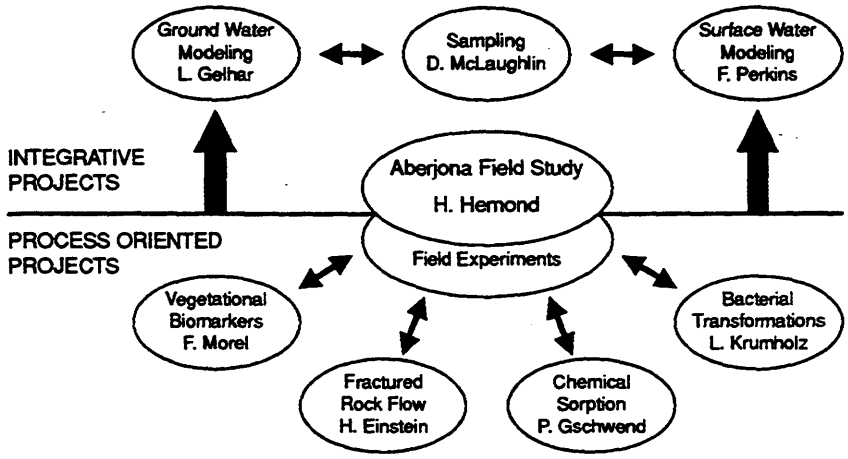
Air Quality Program
The Air Quality Program is led by Professor Adel Sarofim of Chemical Engineering. It combines faculty in Chemical Engineering, Materials Science and Engineering, Mechanical Engineering, Earth and Planetary Science and Toxicology who study the mechanisms by which organic and inorganic pollutants reach the atmosphere, the oxidative, hydrolytic and photochemical transformation of these chemicals, and the means and forms of deposition of these chemical mixtures in the human lung. We have combined major funding from two NIEHS Project Programs (Health Effects Combustion Effluents, and Superfund Basic Research) with a new "Center Grant" from the EPA to create an identifiable unit. This new unit (MIT Air Quality Program) continues and expands the long standing cooperative efforts of the MIT Energy Laboratory and CEHS.

The Water Quality Program led by Professor Harold Hemond of Civil Engineering is a more recent CEHS development funded principally by the NIEHS Superfund Basic Research Grant and our NIEHS Center Grant. This Program is primarily a cooperative endeavor between the faculty of the Parsons Laboratory for Water Resources and Environmental Engineering and Center for Environmental Health Sciences.

Water Quality Program

Specific research projects addressing fundamental scientific questions have been articulated around a central field project dealing with the movement of hazardous chemicals in the Aberjona Watershed northwest of Boston. This field project has been funded through the NIEHS Superfund program and a specific project on bacterial mutational spectra in polluted aquifers has received funding from the EPA Northeast Hazardous Substances Center. Five new projects have received support within the past three months. In addition, one project has received seed funding from the CEHS.

The general objective of this section of the CEHS is a quantitative understanding of the degree of human exposure to hazardous waste via drinking water and recreational exposure. Our approach is to use a combination of mechanistic, process - oriented projects and integrative modelling projects all linked methodologically and thematically with the Aberjona field project (see Figure below). The field project provides a common focus for the individual projects and insures the overall focus of the research on public health. The individual projects extend the field study beyond the particulars of the Aberjona Valley to provide results of general applicability at hazardous waste sites.



Led by Professor Hemond, the Aberjona field project has now established much information regarding the sources and transport of hazardous chemicals in the watershed: historical records, hydrologic monitoring, flow model, mutagenic activity, toxic metal occurrence, speciation and transport, occurrence and fate of volatile contaminants. With the funding of five new projects, the work has expanded to include studies of chemical sorption in aquifers, micromodelling of ground water flow conditions, optimal sampling, bioremediation, fractured rock flow and the use of vegetative stress responses as biomarkers. The program aims to provide a strong basis for the proposed and now funded study of chemicals and patterns of genetic change in the human residents of the Aberjona Basin.

During the current budget period, specific knowledge of chemical contamination and migration on the Aberjona Watershed has been expanded on many points. Several sites and issues of high scientific and public health interest have been identified. Some of the highlights are as follows: *Toxic Metals:* We have now shown that not one, but two major episodes of severe metal contamination have occurred on the Aberjona Watershed, the earliest between 1890 to 1935 and the second around 1960. Chromium, arsenic, cadmium, and lead were first measured. Within the past year, mercury contamination has also been documented. The occurrence of the second episode of contamination is not directly suggested by the literature or by historical records and is of special concern because it may have contributed toxic metals to wellwater supplied to the city of Woburn. Ongoing work has been documenting the mobilization and chemical speciation of contaminants in several accessible sites on the watershed, including upper and lower Mystic Lakes and a small lake (Halls Brook Storage) in North Woburn. *Mutagens:* Our first studies found that bacterial mutagens were present in many squatic sediments on the Aberjona Watershed. Mutagenicity to human cells has now been confirmed many times in sediments of one site: Wedge Pond in Winchester. This important result is now being followed up with a major effort to isolate and identify the responsible compound(s). *Volatile Chemicals:* Work on measuring the rate and location of volatile contaminants (notably benzene, toluene, TCE, and TCA) into the streams and ponds of the watershed has focused on sites identified by our reconnaissance efforts in Wilmington, Woburn and Stoneham. This work is yielding quantitative estimates of potential human exposure, of natural aquifer flushing rates, and of in - stream biodegradation of these pollutants. Detailed studies of toluene degradation in the East Drainage Ditch have begun to reveal the responsible microbial communities. An effort at artificially inducing in-site degradation of TCE has been planned for Sweetwater Brook in Stoneham (Professor Lee Krunholz, Civil and Environmental Engineering). A new salt flow tracer technique has been developed to allow this work to be carried out further down river in higher stream flow. *Aquifer Measurement and Modelling:* A detailed model for ground water transport at the wells

G&H Superfund site in Woburn has been implemented. This will expand our capabilities from the earlier less precise models and will help us answer questions relating to the possible subsurface connections of the Industriplex Superfund site with the Aberjona River. We have recently begun field sampling in support of new projects involving Professors Lynn Gelhar, Phil Gschwend, and Dennis McLaughlin (Civil and Environmental Engineering) at this site. We have also begun testing several geophysical methods, including seismic and ground penetrating radar to elaborate the structure of the sediments which influence water and contaminant transport from the Aberjona River to local water supplies.

Community Outreach
Community based research requires an informed and supportive body politic. Not everybody in the Aberjona Basin likes to know that its streams and lakes contain high concentrations of toxic metals or human cell mutagens. We cannot yet explicitly state the relationship between human exposure to these pollutants and some disease outcome such as cancer. The public may rightly consider our efforts in terms of "trouble making" (scares people) and "useless" (yields no specific contaminant to avoid or remove).

We anticipate even greater skepticism as we begin sampling and observing the mutations arising in blood samples of Aberjona families. So far we have addressed these questions in a four year effort of public presentations, use of local cable television and many articles in the local and regional newspapers. This year more steps will have to be taken. We have outlined a series of explanatory articles for the local newspapers which address the issues head-on.

Already a hold has been placed on the use of Wedge Pond in Winchester as a swimming area solely on the basis of our finding of a marked ability of beach sediments to mutate human cells. Because we had earlier found the beach area clear of toxic metals, a community group worked through the winter to open the beach this summer. These people are disappointed to say the least.

On the other hand, parents of children with leukemia and a number of severe genetic diseases have approached us and voiced their support. We scientists and engineers in CEHS are at a watershed in the Watershed. If we fail to explain our goals, methods and their limitations to the whole community, we risk misunderstanding. If we frankly explain that our best efforts may **not** yield information valuable in improving public health, citizens who don't want bad news without benefit can argue that the studies shouldn't be done at all.

We, however, are confident that we are attempting what must be attempted if we are ever to understand the public health consequences of human exposure to environmental chemicals. We have chosen to develop new technologies for direct human measurements. Our analyses in non human systems allow the prediction that we will obtain important information from human studies. We will try.

NEW INITIATIVES 1992

Lincoln Laboratory
There appears to be a need for a major, possibly a national, facility to measure the patterns of genetic change in humans. Such a facility could represent a major MIT contribution to the field of genetic epidemiology and cancer research. A series of meetings of Lincoln Laboratory and CEHS staff including a "Julia Childs" demonstration of the manual processes by which human mutational spectra are obtained have taken place. Lincoln group leaders are considering the possible ways to bring their organizational and technical strengths to bear on this sophisticated but high volume clinical research area.

Mechanical Engineering and Material Science and Engineering
At the request of the respective department heads CEHS has recruited two junior faculty, Professors Simone Hochgreb and John Lienhard into the Air Quality Program. Professor Hochgreb is preparing a project proposal involving automobile emissions, Professor Lienhard, a project proposal involving a new model to predict particle deposition in the human lung.

Nuclear Engineering
CEHS has begun to help junior faculty develop proposals and expertise in the interface of nuclear engineering and public health. Professor Jacquelyn Yanch has already completed a proposal to discover the mutational spectra of low and high LET radiation in human cells. She proposes to use this knowledge to determine the genetic effects of background or occupational radiation exposure directly in humans. Involvement of another new faculty member with interests in nuclear waste disposal problems is expected this year.

WILLIAM G. THILLY

Harvard-MIT Division of Health Sciences and Technology

INTRODUCTION

The Harvard-MIT Division of Health Sciences and Technology (HST) provides a means of collaboration between Harvard and MIT that makes available educational and research opportunities that could not be exploited as effectively by either institution through its own independent efforts.

HST opens the enormous educational resources of both MIT and Harvard to highly qualified students who seek careers at the the interface of science and engineering with medicine, and develops innovative subject offerings which utilize the faculties and facilities of both universities. The MD curriculum seeks to produce physicians who have a deep and quantitative understanding of the underlying science of medicine and biomedical research. The PhD programs combine rigorous scientific or engineering graduate training with an in-depth exposure to the biomedical sciences and clinical medicine. Both programs seek to prepare students for leadership roles in medicine and biomedical science.

The HST Division facilitates and administers programs in research which are concerned with important biological and health problems which can be addressed in a multidisciplinary manner through the collaborative efforts of biomedical scientists, physical scientists, engineers, and clinicians from the two participating institutions.

ADMINISTRATION

The HST Division is administered by two Co-directors who work intimately with MIT Vice President and Dean for Research J. David Litster, and Harvard Medical School Executive Dean for Academic Programs, S. James Adelstein. Roger G. Mark, Grover Hermann Professor of Health Sciences and Technology, is the MIT Co-director. In March 1992, Dr. Michael Rosenblatt was appointed as the Robert Ebert Professor of Molecular Medicine at Harvard Medical School, and the Harvard Co-director for HST. He was formerly Senior Vice President for Research at Merck Pharmaceutical Company. Dr. Rosenblatt also directs the Bone and Metabolism Division of the Department of Medicine at Beth Israel Hospital.

The external HST Advisory Committee visited the Division for two days in April 1992. The focus of their intensive review included the administrative structure of HST, a review of proposed new HST initiatives, and the present academic programs of the Division. Their report to the Provost of MIT and Dean of Harvard Medical School contained a number of important and provocative assessments and recommendations.

ACADEMIC PROGRAMS

A total of 233 graduate students were registered in HST degree programs during the academic year. There were 178 MD candidates of whom 73 were simultaneously pursuing PhD degrees. There were 62 students registered in the doctoral program in Medical Engineering and Medical Physics. Six students were enrolled in the Radiological Sciences Joint Program which is sponsored jointly by HST and the Nuclear Engineering Department. HST offers approximately 50 courses in the biomedical sciences and biomedical engineering, some of which have been developed jointly with other MIT departments. Approximately 155 faculty members at MIT (42) and at Harvard Medical School (113) contribute significantly to the academic programs of HST. HST has a "core" primary faculty only numbering 7 individuals.

The Division launched a new doctoral track in Speech and Hearing Sciences this year, funded by a substantial NIH Training Grant. The new program, directed by Professor Nelson Kiang, involves a number of MIT and Harvard Medical School faculty members. The initial class of eight outstanding graduate students has been admitted, and will begin their studies in September 1993.

A number of new courses were developed and offered for the first time this year. They include HST 522J Biomaterial-Tissue Interactions, HST 550 Space Life Sciences, HST 510 Principles of Human Anatomy (designed for engineering students), HST 240 Physician/Scientist Preceptorship, HST 160 Molecular Biology and Genetics in Modern Medicine. In addition, a number of new Speech and Hearing Science courses are under development. HST 130 Introduction to Neuroscience was completely redesigned under the direction of Dr. Gerald Fischbach, the Chairman of the Department of Neurobiology at HMS.

The use of computers in the medical curriculum has been greatly expanded under the direction of Dr. Robert Greenes of Harvard Medical School. Physiologic simulations, interactive programs of case-based pathophysiology, and interactive quizzes have been integrated into several core courses.

The MD degree was awarded to 27 HST medical students during this academic year, and six students received PhD degrees in Medical Engineering and Medical Physics. One individual was awarded the PhD degree in Applied Biology and in Medicine.

RESEARCH PROGRAMS

A principal objective of HST from its inception has been the development of interdisciplinary, inter-institutional collaborative research between the faculties of MIT and Harvard. The distribution of HST research volume reflects our efforts toward this objective. For the past few years research funds raised have been distributed almost equally to Harvard (including affiliated teaching hospitals) and MIT (including both primary and secondary volumes). At MIT, faculty members from several departments: (Aeronautics and Astronautics, Chemical Engineering, Electrical Engineering and Computer Sciences, Biology, Mechanical Engineering, Chemistry, etc.), have been participating in HST research activities. The total projected fiscal year '92 research volume is $7, 244, 612. The research activities and funding of the Clinical Research Center, organizationally part of HST, are reported separately.

FACULTY STAFF

Richard J. Cohen was promoted to full Professor of Health Sciences and Technology beginning July 1, 1992.

Martha Gray (primary appointment in EECS) was promoted to Associate Professor of Electrical and Medical Engineering (without tenure) beginning July 1, 1992. She will continue to hold the Kieckhefer development chair.

Dr. James Weaver was promoted to Senior Research Scientist beginning July 1, 1992.

The faculty appointment of Nelson Kiang was transferred from Brain and Cognitive Sciences to HST July 1, 1992. He will retain a joint appointment in Brain and Cognitive Sciences.

The Irving M. London Teaching Award was given to Professor Frederick J. Schoen, MD, PhD, Associate Professor of Pathology at Harvard Medical School and Lawrence J. Henderson Associate Professor of Health Sciences and Technology. The award recognizes the excellence of his teaching as head of HST 030 Human Pathology.

Professor Martha Gray was given the Ruth and Joel Spira Award for excellence in teaching by the Department of Electrical Engineering.

Roger G. Mark

Technology Licensing Office

MISSION

The mission 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 subsequent sale of commercial products. A secondary goal is to generate unrestricted funds to motivate inventors and to support research and education at MIT. The TLO staff of 20, with 11 professionals and nine support personnel, are responsible for identifying marketable technologies, managing the patenting and copyrighting of these technologies, finding licensees to develop the technologies and negotiating licenses.

FY '92 ACCOMPLISHMENTS

Fiscal Year 1992 was an exceptional year for the Technology Licensing Office. Our gross income, originally forecast to be $5 million for the year, was $16 million. Of this, $8.6 million was received from cash-in of equity from startups. This number was unexpectedly high because several start-up companies took advantage of the Initial Public Offering "window" in October, 1991 and went public. Under MIT policy we booked the income when the stock was either i) added to the endowment or ii) sold by the Treasurer's Office.

An additional $5.7 million of our gross income was from cash royalties (up from $3.6 million in FY '91), and the remaining $1.7 million was from patent cost reimbursement payments, certain research and technology transfer payments related to licenses, interest, and other fees.

New invention disclosures increased to 364 in FY '92, up from 280 in FY '91, indicating investigators' increased interest in technology transfer.

We continued an active licensing and technology transfer program for Lincoln Laboratories which now accounts for 20 percent of our new invention disclosures and a similar fraction of new licenses.

ADMINISTRATIVE

This year we completed a project with Information Systems to redesign our computerized database and accounting systems. The new system went on stream in April, and is working well. The automated invoicing system is expected to substantially reduce outstanding accounts payable. Inventor and department royalty-sharing disbursements will be greatly accelerated, allowing us to make these payments in the first 90 days of the fiscal year.

PERSONNEL

We hired a new Office Manager/Patent Administrator, Jarmila Hrbek, and a Sponsor Compliance Administrator, Michelle O'Shea. Both are transfers from other MIT Departments. Dorene Sorensen, formerly our Patent Administrator, has become an Administrative Assistant in the Office. Peter Richards, our Software and Trademark Licensing Associate, has resigned; a replacement is being sought. An additional office assistant will be added in early FY '93.

JOHN T. PRESTON

Center for Cognitive Science

For the past thirteen years the MIT Center for Cognitive Science served as a major focal point for theoretical work relating to cognitive science at MIT. It's Policy Setting Group, the so-called Working Group, consisted of MIT faculty from three departments (Electrical Engineering and Computer Science, Psychology, and Linguistics and Philosophy) and two laboratories (the Research Laboratory of Electronics and the AI Lab). Spurred by a two and a half million dollar grant from the Sloan Foundation, the Center constructed and maintained a much needed human subjects laboratory capability for the then Department of Psychology as well as offering itself as a bridge between Psychology on the one hand and Linguistics and Philosophy on the other. In recent years these Center functions have been superseded by structural change at MIT and by technological development. In particular the formation of the Department of Brain and Cognitive Science and the advent of more powerful local work stations rendered much of what the Center did unnecessary. Furthermore, Center funding, which had lasted for thirteen years, finally came to an end, although not an abrupt one since there are still small sums available to support two of the Center's remaining activities, the Colloquium Series and its Occasional Paper series. However, with the coming academic year (1992-93) the Center for Cognitive Science enters its fourteenth year of operation. It seems like an appropriate time for the Center's Working Group to take stock and make recommendations for the future.

As mentioned above all Center activities have ceased except for two, the MIT Center for Cognitive Science Colloquium series and the MIT Center for Cognitive Science Occasional Paper Series. In the latter series two publications were offered this past year. With respect to the former this year's series included the following presentations.

Professor Jerry Fodor, of Rutgers spoke on "Modularity and Parsing." Commentators were Professors Lyn Frazier of the University of Massachusetts at Amherst and Ray Jackendoff of Brandeis.

Members of the NSF Training Grant group in *Language Acquisition, Computation, and Use* discussed the topic, "Binding Theory and Language Acquisition?" Discussants from MIT included Professors Irene Heim, James Higginbotham, Ken Wexler, David Pesetsky and Alec Marantz.

Professor Michael Jordan of The MIT Department of Brain and Cognitive Science presented a paper entitled "Supervised learning: The Problem of the Teacher" with Professor Christopher G. Atkeson of MIT as commentator.

Professor Renee Baillargeon of the University of Illinois presented a paper on "The Development of Infants' Physical Reasoning" with Professor Susan Carey of MIT as commentator.

Professor Mark Liberman of the University of Pennsylvania spoke on the topic "When is Positive Evidence Negative Evidence?" Commentators were Professors Robert Berwick and Ken Wexler of MIT.

Professors Edward Gibson and Ken Wexler of MIT presented a paper entitled "Triggers and Parameter Setting" with Professor Ken Safir of Rutgers as commentator.

A total of between three and four hundred interested individuals from the Greater Boston area attended this series this past year. The Center anticipates that the number of colloquia will be increased during the coming year as a result of the successful application to the National Science Foundation for a Research Training Grant to MIT in *Language Acquisition, Computation, and Use*. The Center will continue to coordinate this activity.

SAMUEL JAY KEYSER, Co-director

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, oxides that superconduct at high temperatures, and very small atomic clusters ("quantum dots") with properties markedly different from the bulk. They are very recent examples of unanticipated discoveries that took the materials community by storm and captured the imagination of the press. Among the reports of several commissions and panels that have identified materials as an area ripe for exploitation, the National Research Council report, *Materials Science and Engineering for the 1990's*, states in the opening lines of its preface 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."

The establishment of the Center for Materials Science and Engineering resulted from similar feelings, far ahead of their time, 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. 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, and continues to have, three objectives, including provision of 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.

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, to the mechanism of superconductivity in oxides, to the synthesis and measurement of properties of novel polymers. A newly-formed team has begun study of the structure and transport properties of interfaces in ceramic oxides. An overview of the research in each of these four areas-of-thrust, as well as the projects that operated under seed support, is provided in the following sections. In aggregate, CMSE supported projects for 41 principal investigators drawn from eight different departments--on the order of one-third of the departments that exist at MIT. Individual descriptions of these projects are among those included in *Research in Materials, Annual Report* (ca. 500 pp. in 1992) and in the *Polymer Research Annual Report* (ca. 100 pp.) compiled, published, and widely distributed by CMSE on behalf of the broader materials community at MIT.

CMSE provides indirect research support to the broader MIT community through the nine central research facilities that were operated during 1991-92. These laboratories provide services that range from chemical analysis and machining to unique and state-of-the-art apparatus available for analysis with electron microscopy, surface probes, or X-ray scattering. The facilities are available to qualified users in return for modest user fees that provide partial recovery of operating costs (but not capital expenses). When capacity permits, the laboratories are made available to sister institutions or (provided comparable services are not available in the commercial sector) to commercial organizations. On the order of two-thirds of the activity in our central facilities was associated with non-CMSE-supported projects in 1991-92.

The interdisciplinary flavor of the research that is conducted within CMSE, combined with the hands-on, "open shop" basis on which our central facilities are operated, provides an exceptionally rich environment for the training of undergraduate, as well as graduate students. During 1991-92, CMSE provided funding for the support of 21 semesters of UROP activity for 16 undergraduates registered in five different academic departments.

Faculty, in addition to serving as principal investigators of thrust-area and seed research projects, participated in the operation of CMSE in two important ways. Each central research facility has a faculty advisor (in addition to one or more research specialists who serve as laboratory supervisors) who provides technical guidance, as well as advice to CMSE on needs, trends, and new developments in the instrumentation provided by that particular facility. Service in this volunteer capacity is sometimes the only connection between a faculty member and CMSE. In addition, faculty provide invaluable assistance in guiding the operation of CMSE through service on an Internal Advisory Committee (IAC). This group, composed of the faculty members who serve as thrust-area leaders, as well as members-at-large selected to broaden representation of departments and central facilities, review requests for capital equipment, review and approve proposals for seed-funded projects, and provide recommendations on space changes, priorities, and overall CMSE policy. During the past year, the IAC membership consisted of Professors Robert E. Cohen, Carl W. Garland, Mehran Kardar, Marc A. Kastner, Michael F. Rubner, Robert J. Silbey, John B. Vander Sande, and the CMSE director.

CMSE played a further role in the educational programs of the Institute through the presentation of a number of minicourses and IAP programs. Several of these programs were designed to introduce students to the capabilities and operation of the instruments housed in our central facilities. CMSE also sponsors a weekly colloquium series. The program for the spring semester of 1992 again highlighted the research activities of one of the CMSE-supported areas-of-thrust (in this instance, AT-IV, Structure and Transport Properties of Grain Boundaries and Interfaces) in what has become a tradition. Support that would ordinarily have been provided for a series of individual outside speakers was instead used to bring a prominent, world-recognized authority in the topic to the MIT campus for a more extended period of interaction with students and faculty and the presentation of a coordinated series of lectures. The Third CMSE Distinguished Visiting Scholar, nominated by members of the thrust area, was Dr. Felix Greuter, Head of the Polymers and Electroceramics Group, Asea Brown Boveri Corporate Research Center , Baden-Dättwil, Switzerland, well known for his studies of the properties of interfaces in electrically-active ceramics.

PERSONNEL CHANGES

Most CMSE-supported research is conducted by students and faculty associated with individual academic departments. Personnel specifically appointed to the CMSE staff consist of the director and an administrative staff in CMSE headquarters and somewhat less than a dozen members of a research, technical, and service staff. The latter are primarily research specialists charged with maintenance of the apparatus in the CMSE central facilities and instruction and assistance of users in their operation. A number of postdoctoral fellows or visiting scientists hold appointments through CMSE when their research is in collaboration with a member of our research staff or, for historical reasons, as a service to the faculty of one or two departments having faculty housed within CMSE.

Within CMSE headquarters, Karen Fosher has been promoted to accounting assistant as a consequence of increased responsibility. Edward Jacobsen continued as a member of the CMSE staff and has been reclassified as an administrative assistant. His area of responsibility, however, was transferred from CMSE headquarters to the Laboratory for Advanced Solid State Laser Materials. Among members of the CMSE technical staff, David Gabbe, research scientist, and Helena Goldfarb, member of the senior technical staff, have retired. Elisabeth Shaw was reclassified as a research specialist.

The great majority of the personnel changes during 1991-92, as is usual, consisted of short-term appointments of postdoctoral associates and visiting scientists, or the resignation of such individuals upon completion of their intended visits. Appointments as visiting scientists were extended to Doctors Alexandre Broniatowski, Renaud R. Metz, Remy Stoll, Irina Mnuskina, Mauro Tonelli, and Yasuhide Yamaguchi. Appointed as postdoctoral associates were Doctors Lezek Hozer, Mikhail Noginov, and David Knowles. Resignations from short-term appointments were received from Doctors Hiroyuki

Arioka, Alexander Broniatowski, Anton G. Failla, Mark Garrett, Takehiro Hyuga, David Knowles, Kazuyoshi Kuriyama, Jong Tae Park, and Remy Stoll.

CURRENT RESEARCH

Brief descriptions of the general nature of the past year's research, a few highlighted accomplishments, as well as a history of faculty participants, are provided in the following sections for the four areas-of-thrust funded by CMSE. Brief mention is also made of the seed grants that were awarded to individual investigators. Work concerned with deformation and fracture of high-temperature materials did not receive long-term funding for the three-year cycle of our MRL grant that began March 1, 1991. This effort was largely phased out during the first year of the program. Two projects, however, were extended into the present year to permit graduate students to complete their thesis research. Professor Regis Pelloux (Materials Science and Engineering) concluded an examination of low-cycle fatigue resistance of Al-Ti-Nb alloys relevant to application in turbine rotors. Professor Lallit Anand (Mechanical Engineering) in a related study, brought to completion an investigation of the cyclic deformation resistance of CMSX-3 and CMSX-4 alloys.

Transition Metal Oxides

Initiated shortly after the surprising discovery of superconductivity in La_2CuO_4, the goal of this thrust-area team is the deeper understanding of the transition metal oxides in which the strongly correlated motion of electrons lead to novel magnetic and transport properties. Previous work on the prototype La cuprate, in which charge is transported by holes, has been extended to the electron-doped materials $Nd_{2-x}Ce_xCuO_4$ and $Pr_{2-x}Ce_xCuO_4$. Magnetic and transport measurements were pursued by Professors Robert Birgeneau and Marc Kastner using single crystals grown by Dr. Hans Jenssen. Professor John Graybeal produced thin films of the Nd cuprate to permit property measurements that would be difficult or impossible with bulk crystals. Professor Hans-Conrad zur Loye was engaged in the synthesis of new families of materials that may display correlated electron behavior, while Professor Patrick Lee addressed the very difficult problem of constructing a theory that describes highly-correlated, two-dimensional electron systems. During the past year, new neutron scattering measurements have shown that, in contrast to $La_{2-x}Sr_xCuO_4$, the behavior of the Nd cuprate may be understood in terms of simple dilution of the Cu spin system. Spin-scattering from $La_{2-x}Sr_xCuO_4$ has shown that spin excitations persist well below the critical temperature of 33 K and at energies as low as 1.5 meV, well below the weak-coupling BCS gap of ca. 10 meV. This is inconsistent with BCS s-wave superconductivity in any model in which the electrons are strongly coupled to the charge carrier. Contrary to the assumption made in most theories, there is no electron hole symmetry for the Cu-O layer. The recent neutron scattering results have provided the most convincing evidence to date that the superconductivity is not conventional and requires more esoteric physics for its explanation.

Participating faculty and departmental affiliation: Professors R. J. Birgeneau, J. M. Graybeal, M. A. Kastner, P. Lee (Physics); H.-C. zur Loye (Chemistry); and Dr. H. P. Jenssen (CMSE Principal Research Associate).

Phases and Phase Transitions

The research of members of this area-of-thrust involved experimental and theoretical investigations of phase behavior and phase transitions in complex structured fluids. Calorimetry and scattering methods that employ light, X-rays, or neutrons constituted the principal experimental tools. Theoretical models, based upon statistical mechanics, were employed in efforts to describe the behavior of these phases. The effort involved three closely interrelated areas of research. Professors Nihat Berker, Robert Birgeneau, Carl Garland, Mehran Kardar, and J. David Litster dealt with thermotropic liquid crystal materials, with emphasis on hexatic phases and smectic phases of polar compounds. The studies concerned the novel phases and phase transitions that occur in pure compounds and binary mixtures, and attempted to interpret the effects of spatial dimensionality on the nature of the phases and the frustration effects that can occur in mixtures. A second area of activity concerned systems in which a solvent played an important role in micellar solutions, protein solutions, and microemulsions. Professor George Benedek formulated a detailed form for the Gibbs free energy for crystallization of proteins from solution, the essential first step in any effort directed toward characterization of their three-dimensional structure. The model was successful in explaining the broad range of experimental conditions under which crystallization can take place and advances an activity that had been largely empirical in character.

Professors Garland, Kardar, and Toyoichi Tanaka have been engaged in the third research focus in this thrust--experimental and theoretical examination of extended networks, including 3D cross-linked polymer gels and 2D membranes. Professor Kardar has performed Monte Carlo simulations that have provided remarkable insight into a debate that concerns whether polyampholytes adopt a swollen or compact configuration in solution. Polyampholytes are polymers that bear positive and negative charges randomly dispersed along the chain. They are the simplest prototype of linear molecules such as complex proteins or DNA. The state of conformation was found to depend critically on whether the polyampholyte is neutral or charged, reflecting, in turn, its conditions of preparation. Strong Coulomb forces in an organic solvent ensures the neutrality of the polymer, which then compactifies or crumples as a "microelectrolyte" to screen charges. If the polymer instead is prepared in a solution in which the Coulomb forces are screened, the imbalance of positive and negative ions is sufficient to stretch the chain.

Participating faculty and departmental affiliation: Professors C. W. Garland (Chemistry); G. B. Benedek, A. N. Berker, R. J. Birgeneau, M. Kardar, J. D. Litster, and T. Tanaka (Physics); Daniel Blankschtein (Chemical Engineering); and Sow-Hsin Chen (Nuclear Engineering).

Synthesis, Properties, and Morphology of Novel Polymers and Block Copolymers

The macroscopic properties of polymers result from interaction between molecular properties and polymer microstructure. Seven faculty drawn from four departments have collaborated in research to understand such interactions. Their research involved synthesis of materials by means of novel ring-opening metathesis polymerization reactions combined with study of optical and morphological properties and measurements of electrical conductivity and toughness. The materials have included homopolymers, di- and triblock copolymers, and polymer blends of glassy thermoplastics and rubbery toughening agents. Professors Ali Argon and Robert Cohen have continued their collaborative study of toughening via a mechanism believed to arise from local plasticization of crazes via enhanced solubility of the rubbery component. Professor Robert Silbey performed theoretical analyses of the electronic and optical properties of conjugated polymers and, in collaboration with Professors Richard Schrock and Cohen, has measured the linear and nonlinear optical behavior of polyacetylene and norbornene. Professor Mark Wrighton has measured the electrical conductivity of well-characterized polyacetylene as a function of its redox state. Professor Michael Rubner fabricated unusual thin film structures of electrically conducting molecules and has found striking properties. Crystalline conjugated polymers, in particular some that contain rod-like molecules, have been the subject of the research of Professor Edwin Thomas. The unusual microdomain structures that result from phase separation of block copolymers that have strong dissimilarity in their repeat units have unexpected applications. Professors Schrock and Cohen had earlier attached metal atoms to one of the block copolymer phases separated into lamellar microdomains. A relatively mild chemical or heat treatment produced a collection of monodisperse metal particles confined to one set of domains. In an extension of this work during the past year, they have produced a microstructure that contains a uniform distribution of spherical microdomains of a diblock copolymer with silver atoms attached to one of the group. Decomposition of the silver complexes by heating produced silver clusters of 55Å diameter, monodisperse to within 20%. Only one cluster was formed within each domain and many were single crystals. Such "quantum dots" are currently of great interest as they have optical and electrical properties intermediate to molecules and bulk material.

Participating faculty and department affiliation: Professors A. S. Argon (Mechanical Engineering); R. E. Cohen (Chemical Engineering); M. F. Rubner and E. L. Thomas (Materials Science and Engineering); R. R. Schrock, R. J. Silbey, and M. S. Wrighton (Chemistry).

Structure and Transport Properties of Grain Boundaries and Interfaces

Grain boundaries and interfaces play critical roles in the properties of materials. Indeed, the properties of certain "electrically active" ceramics, such as varistors and thermistors, derive from the trapping of electrical charge at grain boundaries. Little is known of the fundamental structure and intrinsic properties of boundaries in ceramic oxides. Impurity segregation to boundaries is ubiquitous in oxides, and few experimental probes were available for the characterization of atomic scale structure and chemistry as boundaries are essentially two-dimensional entities. Motivated, in part, by the fact that unprecedented instruments have become available for such analyses and, in part, by the fundamental need for such understanding, this area-of-thrust was initiated in March 1991. In the past year, Professors John Vander Sande and Robert Balluffi began study of grain boundaries in general orientation, using a

combination of modeling and high-resolution transmission electron microscopy. In collaboration with Dr. Paul Bristowe, they have assembled and tested computer codes that permit evaluation of the energies of defect formation and migration at boundaries with the atomic configuration so determined. Professor Harry Tuller assembled an instrument that permits deep-level transient spectroscopy of deep electronic traps at or near the vicinity of a grain boundary. He has obtained the first high-resolution spectra for ZnO, an important varistor material. Professor Yet-Ming Chiang has used quantitative measurement of aliovalent solute segregation in the space charge adjacent to individual grain boundaries as an experimental probe of the grain boundary space charge potential in TiO_2. Professor Bernhardt Wuensch, with the aid of a novel chemical vapor transport apparatus, has synthesized MgO bicrystals of controlled orientation. The boundaries should be free of segregated impurity as the bicrystals may be fabricated in times sufficiently short that diffusion distances are limited to a few unit cells. Oxygen self-diffusion rates are to be measured with ten specimens, and their structural and electrical characteristics determined in collaboration with other members of the thrust area.

Participating faculty and departmental affiliation: Professors R. W. Balluffi, Y.-M. Chiang, H. L. Tuller, J. B. Vander Sande, and B. J. Wuensch (Materials Science and Engineering).

Seed Research

Twelve seed projects were funded for faculty members affiliated with five different academic departments for all or a part of the year 1991-92 (including three initiated in June 1992). As mentioned above, seed support is awarded primarily to new or recently-appointed faculty. Support is occasionally provided to a more senior investigator when the project may likely be incorporated into an area-of-thrust, or for a short-term feasibility study that holds promise, but involves a measure of risk. Seed proposals, in the past, were welcomed for consideration at any time of year. In 1992, however, CMSE adopted a policy of soliciting proposals only in June or September, both to avoid uncertainty in the continuation of appointment of graduate students who held research assistantships supported by the grant (MRL funding is renewed on March 1), as well as to make the award of funding coincide with the time when new graduate students become available for assignment to a project. Five seed projects were concluded during the past year. Professor Jésus del Alamo completed a highly successful demonstration of coherent quantum tunneling between two closely spaced electron wave guides in a semiconductor device termed a "Quantum Field-Effect Directional Coupler." Professor Manuel Oliveria developed a sputtering system that allowed fabrication of composite films of a ferromagnetic metal and a ferrimagnetic oxide with microstructure in the nanoscale region. His work progressed sufficiently that he was able to secure funding from an outside source. A similar success in locating other resources resulted in conclusion of support for Professor Mary Boyce's study of aging in the structure and plastic flow of glassy polymers. Professor Boris Altshuler concluded theoretical study of quantum effects that led to the surprising conclusion that the free electrons in a metal not only sense motion of a single impurity atom, but can influence it. His recent work focussed on the magnetic-field dependence of the energy shifts. Professor Leonid Levitov had made the intriguing observation that the Fibonacci sequences that occur in many biological structures are a general property of a compressible lattice. His project attempted to apply this theory to physical systems as diverse as flux lattices in layered superconductors and the formation of superstructures in Al-Ni-Cu alloys. In addition to the work of Professors Altshuler, del Alamo, and Oliveria mentioned above, two continuing seed projects also dealt with the fabrication of properties of nanoscale materials, an area that is currently of great interest. Professor Moungi Bawendi and Kirk Kolenbrander have begun synthesis of "quantum dots," nanometer-scale atomic clusters, by two alternative routes: the former by chemical decomposition reactions; the lattice by superionic expansion of laser-evaporated material. Initial funding was also awarded to Professor Xiao-Gang Wen who, in work strongly connected to the thrust on transition metal oxides, is attempting to apply spin-liquid theory to the oxide superconductors. Professor Philip Phillips has theoretically examined the role of disorder in the metallic state of conducting polymers that have non-degenerate ground states. He has demonstrated the applicability of a unique model for the role of extended states in a one-dimensional disordered system. New seed grants have been recently awarded to Professors Gerbrand Ceder for advanced modeling of phase equilibria and to Professor David Dunand for study of aspects of martensitic phase transformations.

Participating faculty and departmental affiliations; concluded projects: Professors B. Altshuler and L. Levitov (Physics); M. Boyce (Mechanical Engineering); J. A. del Alamo (Electrical Engineering and

Computer Science); M. Oliveria (Materials Science and Engineering). Continuing projects: Professors M. G. Bawendi and P. W. Phillips (Chemistry); K. D. Kolenbrander (Materials Science and Engineering); X.-G. Wen (Physics). Projects initiated June 1, 1992: Professors G. Ceder, D. Dunand, and M. Rubner (Materials Science and Engineering).

Laboratory for Advanced Solid State Laser Materials

Growth of fluoride crystals for lasers and other applications has been an ongoing effort for the Laboratory for Advanced Solid State Laser Materials. Fluoride perovskite crystals have been studied as potential substrate material for high-T_c superconductor electronics and a new material, $NaMgF_3$, was grown for the first time in this program. Under Office of Naval Research and National Aeronautic and Space Administration sponsorship, laser materials where energy transfer can be either a useful or an unwanted effect have been studied. For example, in the new Cr-doped tunable fluoride laser crystals, we have found a very large unwanted upconversion. This will severely limit the amount of chromium that can be used in these crystals. The angular dependence of maximum and minimum optical transition strengths in monoclinic crystals have, for the first time, been studied. The extrema were found to be completely random with respect to the crystallographic and refractive index axes, and were not the same for different optical transitions. The laboratory has cooperative programs with several other institutions, including the University of Pisa, Italy; the General Institute of Physics, Moscow; and the University Claude Bernard of Lyon, France.

CENTRAL FACILITIES

As a consequence of increasing constraints in the funding allotted to the MRL Program by NSF, steps were undertaken in March 1990 to consolidate the thirteen central facilities then supported by CMSE to a total of nine. Four essential services were discontinued, and the reorganization effected a considerable efficiency and economy of scale. This process was largely completed during the past year. The instruments for scanning electron microscopy and for transmission electron microscopy/scanning transmission microscopy, long housed in separate facilities for largely historical reasons, have been consolidated into a single Facility for Electron Microscopy. The arrangement has proven to be an advantage for users as having the expertise of all research specialists housed in a single laboratory permits "nonstop shopping," as it were. Moreover, useful laboratory space has been freed for research. The instruments housed in the facility have experienced substantial upgrading to state-of-the-art and, in most cases, a unique capability, in a series of stages that began in 1989. An ISI/Akashi EM 002B 200 kV transmission electron microscope, the first of its kind, was installed at that date and, after a year-long period of fine-tuning and adjustment, has become fully operational. It is a high-resolution instrument of advanced design, providing 1.8Å point-to-point resolution. An Electroscan Corporation environmental scanning electron microscope, installed in 1990, is also fully operational. This instrument operates on a new principle that eliminates both the need for the specimen to be electrically conductive and the need for high vacuum to be maintained in the specimen chamber. The sample under examination may be viewed in an environmental atmosphere of up to 20 torr pressure. A Vacuum Generators HB 603 scanning transmission electron microscope, the first of its kind to operate at 300 kV, was delivered in the summer of 1990. The electron source is of the field emission type, enabling electron probes 2Å in diameter to be formed. The high operating voltage reduces spreading of the electron beam in the specimen, thus permitting quantitative chemical analysis of areas as small as 3Å in diameter. The instrument produced useful results during the past year, but continues to undergo adjustments by the manufacturer. Vibration and/or stray magnetic fields (despite being shown by survey to be among the lowest levels available within CMSE) apparently continue to interfere with regular operation at the manufacturer's specifications for the instrument. In June 1992, a substantial grant was received from the U.S. Department of Energy's University Research Instrumentation (URI) Program to purchase a Gatan #666-UHV3K PEELS Spectrometer, which will provide a capability for electron energy-loss spectroscopy on the instrument. This important modification will greatly enhance the versatility of the instrument. Other highlights of upgradings of instrumention and improvement of the capabilities of the central facilities are the following. The former Central Analytic Facility and Polymer Central Facility have been merged to form a single Chemical and Thermal Analysis Facility. The available instruments have been augmented by modern apparatus for thermal analysis that operate over an extended range of temperatures: a Seiko DSC-320 differential scanning calorimeter, a Seiko thermogravimetric and differential thermal analyzer, and a Seiko DMS 110-200 dynamic mechanical rheology station. The new facility has enjoyed heavy use during the past year. The capability of the Facility for Crystal Growth has

been expanded through the installation of a float-zone crystal growth apparatus for the growth of refractory materials under controlled atmosphere. Among other applications, the unit will supply the high-quality crystals needed by the members of the thrust area concerned with transition metal oxides. A Perkin Elmer 5100 ESCA (X-ray photoelectron spectrometer) has been acquired with assistance from the Sloan Fund that has improved capability compared with the Physical Electronics 548 XPS Auger spectrometer that presently exists in the Surface Analytical Facility.

OUTREACH PROGRAM FOR MEMBERS OF MINORITY GROUPS UNDERREPRESENTED IN SCIENCE AND ENGINEERING

Projected shortages in the supply of a technological work force, as well as the moral imperative of providing equal access to careers in science and engineering to all members of society, has prompted the NSF to make available funding for educational programs that address the situation. The Materials Research Laboratories, having a broad interdisciplinary setting, have unique qualifications to organize such activities and were invited by the director of the MRL Program to submit proposals for funding of their support. A proposal, researched and written by Susan Rosevear, Publications Coordinator in the CMSE headquarters office, was submitted for consideration. NSF agreed to support the proposed program with funds from both the MRL Program and the NSF Division of Human Resource Development. The activity that is planned is a one-week science and engineering "day camp" for 12-16 seventh and eighth grade students, to be held at the end of August 1992. The premises on which the program is based are as follows. First, a preliminary investigation revealed that MIT does not offer as much for middle school minority students as it does for high school and undergraduate students. We considered it critical to reach students at the seventh- and eighth-grade levels as it is a period of identification with peer groups, as well as the point at which students must decide on a high school curriculum, the foundation of future career choices. Secondly, most existing programs involve tours or lectures. Every group at MIT or in the Boston area that was contacted stressed a need for hands-on involvement. Consequently, the day camp will consist of a limited amount of lecture time and will focus primarily on hands-on laboratory projects designed to have the students explore the nature of materials as a vehicle for providing a view of the nature of science and engineering in general. Metal working, glass blowing, and electron microscopy are some of the activities planned. They will be conducted primarily in CMSE central facilities with the assistance of volunteer members of the CMSE staff and several faculty members. To help supervise the student participants, four MIT undergraduates, selected from a large number of applicants and themselves members of minority groups, will participate as "counselors." They will serve as individuals to whom the middle schoolers may more easily relate, but will also serve as role models providing insight into the college experience. We like to think, as well, that the MIT students will derive satisfaction from the objectives of the program. A partial measure of their enthusiasm is the fact that most of them will have to leave summer employment and return to campus one-half month ahead of schedule.

Finally, it was considered appropriate for the Institute to conduct a program close to home. As fifty-five percent of the students in the Cambridge school system are members of minority groups, the Center approached the Cambridge school system about local student participation. The school department staff was highly enthusiastic (and, indeed, while wishing that *all* students could be invited to participate, appreciated the constraints imposed by the source of our funding). As a consequence, middle school students invited to participate in the initial day camp will be drawn from the Fletcher School, which is located virtually on MIT's doorstep. In addition, with the assistance of the school department, CMSE has enlisted the services of a highly-motivated science teacher, also from the Fletcher school, who has handled the selection of participants from his classes. (Student selection was based on interest and behavior patterns, not academic performance.) He will also assist in formulating the curriculum for the day camp, help with interpreting material for the middle-school level, and participate in evaluation of the impact of the program. The student participants will return to CMSE and their counselors on four Saturdays or school holidays during the 1992-93 school year to reinforce the summer experiences. The day camp to be conducted during the summer of 1992 is viewed as a pilot project. If successful, it will likely be funded on an expanded scale for the summer of 1993.

BERNHARDT J. WUENSCH

Clinical Research Center

INTRODUCTION

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. The CRC was the first federally supported clinical research center located in a university and not within a hospital. It was anticipated that in spite of its university venue, a large enough number of qualified physicians from MIT's faculty and staff would utilize the CRC to study normal volunteers and patients with chronic diseases to warrant its existence.

Scientists and physicians authorized to carry out research protocols using the CRC's facilities include: professors; research scientists who work exclusively at MIT; and those with primary appointments in local medical institutions whose research interests overlap extensively with those of MIT investigators. Research protocols must be approved by the MIT Committee on the Use of Humans as Experimental Subjects (COUHES) and the CRC Advisory Committee before they can be implemented. The CRC Advisory Committee, chaired by Professor John Burke, consists of ten voting members plus six non-voting members of the CRC's Program Staff. The Committee reports to the Principal Investigator, Professor Roger G. Mark, and meets bi-monthly to evaluate protocols for their scientific quality, experimental design, statistical analysis and potential risk to human subjects. The Committee also sets general policies and reviews the operations of the CRC.

ADMINISTRATION

In July 1991, Professor Roger Mark, the Co-Director of the Harvard-MIT Division of Health Sciences and Technology (HST), became the Principal Investigator of the CRC grant, replacing Professor Kenneth Smith.

The CRC presently has a dual administrative locus within MIT. As a research unit, the CRC reports through HST to the Vice President and Dean for Research, Professor David Litster. However, as a patient-care unit, the CRC is a part of the MIT Medical Department and reports to Dr. Arnold Weinberg, the Director of the Medical Department. Members of the CRC participate in the Medical Department activities; i.e., Quality Assurance, Pharmacy and Therapeutics, Medical Records, and Safety Committees.

In October, 1991, the CRC submitted a competing renewal application to the NIH GCRC program. This was reviewed by a Site Visit Committee in November, 1991, and the CRC received the highest priority score assigned to any of its renewal applications over the last decade. The Center was recommended for four years of support, which will begin December, 1992.

CORE LABORATORY/ MASS SPEC. FACILITY

The Core Laboratory has focused its investigations more narrowly to reduce routine patient monitoring and to increase laboratory assays that support research. The most important new direction has been the acquisition and amplification of the Mass Spectroscopy Facility for stable isotope tracer analysis . The major purpose of this shared instrument facility is to service the analytical needs of CRC investigators who use stable nuclide tracers in human and metabolic studies. A major focus has been to explore the metabolic basis for and the quantitative estimates of the requirements for nutritionally indispensable amino acids in human adults. Results obtained during the past year add further support for the hypothesis that the specific amino acid needs for healthy adults are probably much higher than has been recommended. Reasons for this discrepancy--which has important implications for nutritional assessment, policy and planning--are being investigated. The role of dietary arginine as a precursor of nitric oxide, a widespread cell-cell communicator and regulator, is being examined using [^{15} N-guanidino] arginine. The novel doubly labelled water ($^{2}H_{2}{}^{18}O$) method is being used to define the energy requirements of elderly subjects, and factors which affect these needs. Preliminary data suggest a higher rate of energy expenditure in older adults than predicted from current international standards.

COMPUTER FACILITY

In September, 1991, we received a $125,000 grant from NIH to replace our old minicomputer, a Digital PDP-11 and our Hospital Services System software, which is the basic system for day-to-day operations of the CRC.

Since last summer, we have installed a new DECsystem 5000 computer, with a network of workstations and terminals. For the first time, the CRC has joined the MIT network and our users can contact colleagues throughout the world via electronic mail. Instead of offering only the outdated Hospital Services System programs written in MUMPS, our new software offerings include two statistical packages, SAS and PROPHET; a relational database management and program development system, INGRES; a word processing package, WORDPERFECT; and other sophisticated systems and networking software packages. The hardware and software are currently being tested by a group of users and will be available to all users by the end of the summer.

In addition to installing the new hardware and software, we have begun to develop our new Hospital Services System using INGRES. We will incorporate in the new system all of the functionality of the old MUMPS system as well as automating many of the nursing, administrative, lab and dietary functions that are now done manually. We have one half-time systems analyst devoted exclusively to the task. We expect the entire project to be completed by the Spring of 1994.

EDUCATION

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 1991-92 nine post-doctoral fellows participated in research projects at the CRC, through the Department of Brain and Cognitive Sciences. At the undergraduate level, seven Undergraduate Research Opportunities Program (UROP) students participated in clinical research projects with physician preceptors and faculty supervisors.

Professor Naomi Fukagawa conducted a Freshman Advisor Seminar sponsored by HST during the past academic year.

On May 15, 1992, the CRC sponsored a research seminar on "Neurodegenerative Diseases." The topics and speakers were:

"Visual Dysfunction in Alzheimer's Disease: Retinal or Cortical?"
Alice Cronin-Golomb, Ph.D.
Assistant Professor, Department of Psychology, Boston University
Visiting Scientist, Department of Brain and Cognitive Sciences, MIT

"Neurotransmitter Control of the Processing of the Alzheimer Amyloid Precursor"
Roger Nitsch, M.D.
Research Fellow, Department of Neurology, Massachusetts General Hospital
Postdoctoral Fellow, Department of Brain and Cognitive Sciences, MIT

"When and How Many Dopaminergic Neurons Die in Parkinson's Disease?"
Yves Agid, M.D.
Professor, Laboratory of Experimental Medicine,
Hôpital de la Salpetrière, Paris, France

"Idazoxan Treatment of Progressive Supranuclear Palsy"
John H. Growdon, M.D.
Director, Movement Disorders Unit, Massachusetts General Hospital
Associate Professor of Neurology, Harvard Medical School

AFFIRMATIVE ACTION

The hiring of women and minorities continues to be a high priority at the CRC, although the primary problem in meeting affirmative action objectives has been attracting qualified minority candidates. The traditional means of advertising and posting positions in local colleges, universities, medical institutions, and minority organizations have not resulted in a significant response from qualified minorities.

This past year three research staff positions became available, and two women and one male were hired. Four research affiliates (all women) were appointed. Three other academic appointments were made: two male Visiting Scientists and one minority female Postdoctoral Fellow were appointed. We will continue our efforts to increase the pool of qualified minority applicants when positions become available.

RESEARCH ACTIVITIES

During the past year, most of the research activities of the CRC have continued to be associated with three clinical areas, and to involve three groups of scientists, each led by a senior professor. These areas are: **Nutrition/ Metabolism** (Professor Vernon R. Young) - an area in which the CRC constitutes the major locus of MIT's activity, and one that is a traditional component of clinical research centers; **Neurochemistry/Neuropsychopharmacology** (Professor Richard J. Wurtman) - studies on the effects of drugs, foods and hormones on brain composition and behavior; studies on biologic rhythms in sleep and hormone secretion; studies on a set of diseases characterized by affective and appetitive symptoms (i.e., depression, premenstrual syndrome, smoking withdrawal, carbohydrate craving, obesity), which seem to relate to brain serotonin; and **Behavioral Neuroscience** (Professor Suzanne Corkin) - focussing on the effects of diseases on cognitive and related brain functions and on genetic and other mechanisms causing neurodegenerative disorders (i.e., Alzheimer's disease). Groups collaborate on multidisciplinary projects, e.g., Obesity; Depression; Alzheimer's disease. Moreover, numerous CRC research collaborators involve both an MIT professor and investigators at an outside hospital or research laboratory.

Besides these three established programs, CRC investigators have conducted research projects involving the development of biomedical instrumentation; the analysis of human autonomic functions (e.g., the contribution of the sympathetic and parasympathetic systems in generating particular electrical frequencies detected by the electrocardiogram); and sensorimotor disturbances.

Dr. Steven Lampert, a Lecturer in Cardiology at the Harvard School of Public Health, and a new investigator at the CRC, has started a research project on the effects of diet on heart rate variability. The project tests the hypothesis that central nervous system autonomic tone, as estimated by spectral analysis of heart rate variability can be altered by manipulating the diet to change the serum concentrations of tyrosine and tryptophan amino acid precursors of the catecholamines and serotonin, respectively.

Preliminary discussions were held with Dr. Otto Harling, Director of the Nuclear Reactor Lab, about having some of the subjects enrolled in his study admitted to the CRC for two-day periods while they are receiving neutron capture therapy for brain tumors and deep-seated skin melanomas.

For the period of July 1, 1991-June 30, 1992, the CRC patient census totaled 350 inpatient days and 2,700 outpatient visits.

RESEARCH HIGHLIGHTS

- Professor Corkin's laboratory demonstrated that the impairment in skill learning associated with Parkinson's Disease was not simply the consequence of motor or perceptual disorders but represented a genuine learning deficit.

- Dr. William Dietz initiated a long-term prospective study of obesity in adolescent girls. These girls will be followed annually over a five-year period to determine whether reductions in energy expenditure contribute to the development of obesity in adolescents.

- Professor Fukagawa has continued to investigate metabolic regulation and nutrition in aging humans. Findings in 68 men and women in two age groups demonstrate that aging per se in humans is associated with altered tissue energy metabolism. The mechanism of this alteration is under investigation; recognition of it may influence our nutritional management of older individuals. Professor Fukagawa's recent work has also shown that old men and women have thermic responses to oral protein which are similar to those of young men. This suggests that it is nutrient composition of test meals which determines differences in thermic responses, not body size, body composition, or dietary intake. These findings may influence future study design.

- Dr. Harry Lynch and Professor Richard Wurtman completed a study that examined the effects of circulating melatonin levels on behavior. They monitored, in 23 healthy male subjects, the overnight serum melatonin profile and performance on a battery of behavioral tasks. Analyses indicate that the varying light intensities did significantly influence nocturnal melatonin secretion and mood. They are currently conducting further analyses to examine correlations between serum melatonin level and performance.

- Dr. Susan Roberts' initial results from studies on energy regulation have provided the first firm evidence that young adults without any history of obesity are unable to dissipate excess energy even when they are permitted to lead normal lives. This finding strongly suggests that the day-to-day regulation of energy balance occurs through the control of food intake rather than the regulation of energy expenditure.

- Dr. Judith Wurtman demonstrated that the premenstrual syndrome is associated with a characteristic disturbance in appetite (i.e., carbohydrate craving leading to weight gain) as well as with symptoms of atypical depression and that both can be ameliorated by drugs which enhance serotonin-mediated transmission in the brain.

- Professor Richard Wurtman and his associates showed that it is possible to design a dietary protein and carbohydrate mixture such that its consumption will neither raise nor lower plasma levels of large neutral amino acids. This effect is highly desirable for patients with Parkinson's Disease taking L-DOPA, since amino acids compete with circulatory DOPA for transport into the brain.

- Professor Young's laboratory accumulated additional evidence supporting their view that present recorded dietary allowances for daily protein intake are inadequate. They also showed that there is considerable less ability, than had previously been believed, for undernourished people to increase the efficiency of calorie utilization by cutting back heat formation.

RICHARD J. WURTMAN

Decision Sciences Program

INTRODUCTION

In May 1992, Professor J. David Litster, the Vice-President and Dean of Research, announced the formation of a new interdepartmental Decision Sciences Program (DSP) at MIT, headed by Dr. Thomas L. Magnanti, George Eastman Professor of Management.

Decision sciences is an interdisciplinary topic emerging in importance in many industries in both service and manufacturing sectors. It is a field that helps to guide individuals and firms in making informed decisions, often concerning the effective use of scarce financial, human, and technical resources. The explosive development of new sources of information and the continuing emergence of ready access to faster and more powerful computers have created both enormous potential and considerable need for more informed decision making. The new Decision Sciences Program aims to exploit these opportunities by developing innovative educational and research programs and by working closely with industry.

ACADEMIC PROGRAM

A primary goal of the new program is to support graduate education in the decision sciences at MIT, enriching ongoing programs like those at the Operations Research Center, and creating new opportunities in statistics and decision processes, for example.

The disciplinary base of the decision sciences ranges from behavioral decision theory and psychology to applied mathematics, economics, operations research, optimal control, and statistics, all topics that help inform individuals and organizations in making decisions. Recognizing the interdisciplinary nature of the field, the DSP will draw upon faculty and student interests from all five schools at MIT and coordinate activities across several existing centers and laboratories. The new program will draw upon existing resources and expertise in other centers and programs, including the Operations Research Center, the Laboratory for Information and Decision Systems, the Center for Transportation Studies, the Leaders for Manufacturing Program, and the Center for Computational Research in Economics and Management Science.

TRANSACTIONAL DATA LABORATORY

A centerpiece of the DSP will be a Transactional Data Laboratory which interprets such data as bar-code laser scanned data from supermarkets, customer interaction data from ATM's (Automatic Teller Machines), materials movement and position data from assembly lines, stocks and options trading data, point of sale data from retailers, and satellite data giving estimates of vehicle locations. The laboratory will be equipped with a sample of new transactional data acquisition technologies, so it will resemble in many ways more traditional laboratories at MIT. In addition to computers, the laboratory will include examples of data acquisition technologies that are giving rise to the gigabyte data explosion.

OUTREACH PROGRAMS

The DSP will actively promote and foster interactions with industry. Such interactions have already begun. Together with the Center for Transportation Studies and the Operations Research Center, the program hosted a seminar entitled, "Symposium on Use of Transactional Data in Transportation and Other Service Industries." On August 11-14, 1992, together with the OR Center, the program will be hosting a major international symposium on information systems and operations research in telecommunications and transportation.

We look forward to the coming year and the possibility of building upon the rich intellectual traditions of MIT in the decision sciences, of creating new opportunities for our faculty and students, and of bridging theory and practice in the best tradition of the Institute.

THOMAS L. MAGNANTI
Director

Division of Comparative Medicine

Introduction
The Division of Comparative Medicine (DCM) provides animal husbandry and clinical care for all research animals on the MIT campus. From its inception in 1972, the Division has evolved into a comprehensive laboratory animal program that provides a full range of veterinary and surgical support. Additionally, the Division has a National Institutes of Health (NIH)-funded training program for veterinarians specializing in laboratory animal/comparative medicine and conducts externally funded research focusing on diseases in laboratory animals. Total personnel in the Division now comprises 62 individuals.

Facility Management and Animal Care
The average daily census of laboratory animals increased approximately 17 percent during FY92. This is a continuation of a four year trend during which the animal census has increased more than 60%. Mice remain the primary species used by MIT investigators and represent more than 90% of the animal population.

The Division was awarded matching funds from NIH to provide improvements in the animal facilities. This is the fifth in a series of NIH grants provided to DCM for such purposes. A germ-free animal facility will be established in E20 to accommodate the increasing use of gnotobiotic technology. A new cage washer and autoclave will be installed in E18 and instrumentation for the diagnostic laboratory will be purchased. Construction is underway on the new biology building which will have a 30,000 gross-square feet animal resource unit to be used primarily for transgenic mice.

Research Activities
The DCM Diagnostic and Investigative Laboratory is in its 17th year of funding. This grant enables the Division to pursue research projects associated with diseases of laboratory animals and development of relevant *in vivo* models. Other NIH-funded grants support *in vivo* study of nitrite carcinogenesis, the study of *Helicobacter pylori* and its relation to gastric cancer, and an examination of the intestinal metabolism of B-carotene. Private pharmaceutical firms have provided funding for the derivation of specific-pathogen-free ferrets, *Helicobacter* research and studies on cartenoid metabolism in ferrets.

FY 92 was the fourth year of the Division's five year NIH postdoctoral training grant. There are currently six postdoctoral trainees, two of whom are enrolled in graduate programs in the Division of Toxicology. IBM has also provided support for one postdoctoral trainee. Demand for veterinarians with training in comparative medicine remains particularly strong in both academia and industry.

Two former postdoctoral trainees passed the board examinations of the American College of Laboratory Animal Medicine during the past year. Glen Otto was the recipient of the Henry and Lois Foster Award for receiving the highest score on the examination. Recruitment for postdoctoral trainees emphasizes the Division's commitment to Affirmative Action. Of the six postdoctoral trainees, two are underrepresented minorities.

DCM faculty and staff published 3 chapters, 27 papers and 16 abstracts in FY92 and presented numerous research papers at national and international meetings.

Regulatory Activities
There have been no changes over the past year in regulations or guidelines concerned with the use of research animals. The Division, in conjunction with the Committee on Animal Care continues to develop the "Psychological Well-Being Program" required by the USDA. The program has been well received by outside regulators.

Teaching Activities
Didactic training sessions were conducted throughout the year by DCM staff in conjunction with the Committee on Animal Care to train Institute personnel on topics pertaining to the care and use of laboratory animals. Additionally, DCM faculty and staff taught the graduate course Toxicology 218.

James G. Fox, DVM
Professor and Director

Energy Laboratory

INTRODUCTION

The Energy Laboratory and its associated Center for Energy and Environmental Policy Research (CEEPR) are multi-disciplinary organizations bringing together sectors of the MIT community with research interests related to energy supply, policy, technology, utilization, and the associated environmental, economic, geographical and societal impacts. Professor Jefferson Tester is the Director of the Energy Laboratory, supported by Associate Directors Drs. Elisabeth Drake and William Peters. Susan Guralnik is the Administrative Officer. The CEEPR is directed by Professor Richard Schmalensee. Dr. A. Denny Ellerman has recently joined the CEEPR as Executive Director; Joan E. Bubluski is the Administrative Assistant.

The Energy Laboratory offers the organizational structure needed for synergistic endeavors that both strengthen and focus energy-related work at MIT; it provides a variety of research opportunities for students at all levels - from the Undergraduate Research Opportunities Program to postdoctoral studies. Our research programs in FY92 involved about 40 undergraduates and 110 graduate students, along with about 65 associated faculty members from about twelve Academic Departments representing all five of MIT's Schools. There is no formal academic curriculum, but many of the faculty associated with the Energy Laboratory teach courses and participate in formal and informal seminars related to energy technologies and their applications.

SELECTED CURRENT ACTIVITIES

Many of the Laboratory's projects involve quantitative and cross-disciplinary study of complex energy and environmental systems. Collaboration with the Center for Environmental Health Sciences (CEHS - directed by Professor Thilly) seeks to determine how combustion emissions and effluents from treatment of hazardous wastes may lead to adverse human health impacts. Other environmental research, in collaboration with the Parsons Laboratory (directed by Professor Morel), focuses on the fate and transport of energy-derived effluents in ground water and aquifers. The Energy Laboratory administers two major experimental facilities for research on stationary and mobile combustors - the Combustion Research Facility (directed by Professor Beer) and the Sloan Automotive Laboratory (directed by Professor Heywood). The Energy Laboratory, in cooperation with the CEHS, also administers the Core Laboratory for Analytical Chemistry (directed by Dr. Lafleur).

Professor Adel Sarofim led a successful proposal effort, with colleagues from MIT, the California Institute of Technology and the New Jersey Institute of Technology, to establish an EPA Center of Excellence in research on sources, atmospheric transport and transformation, monitoring and control of airborne organic compounds. The Center will receive $1 million per year for an initial period of four years. MIT scientists participating in the Center's first year research projects include Professors Beér, Cheng, Heywood, Hochgreb, Howard, Keck, Longwell and Sarofim, and Drs. Peters and Wong.

Energy Laboratory researchers, under the direction of Professor Tester, are completing a Research Needs Assessment Study for the U.S. Department of Energy on the capture and sequestering of carbon dioxide generated from fossil fuel-fired power generating plants. A diverse group of MIT scientists actively participated in this program, managed by Mr. Herzog. Contributors include Professors Edmond, Lee, Peterson, Sarofim and White; Drs. Adams and Drake; Dr. Dacey of the Woods Hole Oceanographic Institute; and five UROP students. This program is providing insights on technological mitigation options that will complement MIT science/policy studies related to global climate change.

Dr. Weiss is directing a major study of the management of environmental remediation activities at Department of Energy sites. Management studies are being coordinated by Professor Carroll; several other faculty and staff are pursuing related technology research. Also, management, sociological and technological issues in improving the safety of existing nuclear power plants, world-wide, are being studied in the MIT International Program for Enhanced Nuclear Power Plant Safety, directed by Professor Hansen; the program involves Professors Carroll, Lang, Lanza, Lidsky, Lyon, Marcus, Rasmussen, and Yip, and Dr. Cooke.

The Electric Utility Program, managed by Dr. Derek Teare, is jointly sponsored by the DOE, a group of international electric utility companies and some of their fuels and equipment suppliers. The Program identifies and funds research

projects of mutual interest. Current research includes three major combustion-related projects in the Combustion Research Facility (Professors Beer and Sarofim) and projects led by faculty and staff in the Laboratory for Electromagnetic and Electronic Systems on the behavior of electrical power apparatus and electric power systems. Other projects involve researchers from the Parsons Laboratory, the Nuclear Engineering Department, the Nuclear Reactor Laboratory, and the Building Technology Program, where Professor Norford is heading a project studying energy consumption in building heating and ventilating systems. Led by Professor David White, researchers in another program use multi-attribute tradeoff analysis to compare alternative strategies that the New England electric utility sector might use to meet future electricity needs economically and in an environmentally sound manner. This project is guided by a diverse group of stakeholders including representatives of the utilities, regulatory agencies and public interest groups.

Other energy conservation initiatives range from industrial process improvements (Mr. Herzog) to advanced building design (Professor Glicksman), including development of models to better understand indoor air pollution (Professor Axley).

A major collaborative program between MIT and the Idaho National Engineering Laboratory seeks new engineering understanding to improve efficiency and materials conservation in energy-intensive processes. This program is directed by Professor White and involves Dr. Drake and faculty from several MIT departments.

As part of their Engine/Fuels Consortium program, funded by four international oil companies and the DOE, the Sloan Automotive Laboratory is conducting research, within the context of the Clean Air Act, on the effects of reformulated fuels on engine performance and emissions. Another project, sponsored by an automobile manufacturer, looks at reducing friction and vibration in engines. They also are evaluating a major performance data base as part of the U.S. auto oil program, involving 14 domestic oil companies and 3 automobile manufacturers.

THE CENTER FOR ENERGY AND ENVIRONMENTAL POLICY RESEARCH

The CEEPR is organized as a joint center of the Energy Laboratory, the Department of Economics, and the Alfred P. Sloan School of Management. CEEPR projects are currently organized under six program areas: 1. environmental economics, management and policy, 2. investment, contracting, and finance, 3. energy industry organization and regulation, 4. energy markets, 5. energy demand, productivity, and economic growth, and 6. technology policy. The Center's program on environmental economics, management and policy is developing rapidly and has nine active research projects in this area. During 1991, the CEEPR published and distributed 16 working papers and released 10 reprints of published papers.

The CEEPR has collaborated with the MIT Center for Global Change Science to form the *Joint Program on the Science and Policy of Global Change,* with the goal of doing the serious interdisciplinary work necessary to provide a more complete, better integrated, and coherent basis for global climate policy development, negotiation, and implementation. This program, led by Professors Jacoby and Prinn, draws on the traditional strengths of MIT, augmented by its formal links to the Woods Hole Oceanographic Institution, as well as strategic alliances with leading research institutions worldwide. Consortium funding will be provided by sponsors in industry, government, and non-profit institutions. Research is now starting under initial funding from several sponsors.

NEW INITIATIVES

Several new projects have been started during the past year. Under the University Research Initiative of the Department of Defense, a five-year fundamental and applied research program on the use of chemical reactors for supercritical water oxidation of military toxic wastes is being conducted for the Army Research Office. Goals are to develop basic kinetic information on oxidation rates, product distributions and salt precipitation rates, models, corrosion data, and reactor simulations that will aid in the eventual implementation of the technology. The project team, led by Professor Tester, will conduct parallel research efforts directed by the following associate principal investigators: Professors Harris, Howard, Latanision, Sarofim, and Smith; Dr. Peters and Mr. Herzog.

The Energy Laboratory is coordinating a faculty group to develop a major new research initiative on new technologies for rapid drilling, tunneling, and cavity creation in rock formations. Important applications include drilling for exploitation of deep petroleum, gas and geothermal energy; mining; and excavation for infrastructure revitalization. Under the leadership of Professor Peterson, a multi-university/industry consortium will be organized to accomplish the

aims of the program. MIT contributions include expertise in engineering (Professors Cleary, Einstein, Tester, and Vandiver) and earth sciences (Professor Toksoz and Dr. Turpening).

INTEVEP, the research and development arm of the National Petroleum Company of Venezuela, has entered into an on-going agreement with the Energy Laboratory to support and collaborate in a diverse array of on-campus research projects. The research projects will team MIT investigators with appropriate INTEVEP research professionals, who will participate in the work through periodic visits to MIT. Benefits from the program include information exchange, state-of-the-art training for industrial professionals, and new industrial support of MIT research. The first projects are expected to start in late 1992.

A multi-year grant proposal has been submitted to the Department of Energy Office of Conservation and Renewable Energy for *Research and Assessment Studies in Support of DOE Programs including analytical capabilities development for research and development and technology transfer related to improved resource conservation and environmental quality.* The proposed program includes workshops, research studies and special tasks. Example research studies were submitted on nine initial topics by Professors Clark, Glicksman, Heywood, Norford, Roos and Schmalensee; Drs. Bozdogan, Drake, and Ehrenfeld; and Mr. Herzog. This program is an outgrowth of prior initiatives on industrial ecology using simulation models for life cycle analysis of technological alternatives considering environmental, safety and economic trade-offs.

Working in synergy with the Joint Program on the Science and Policy of Global Change, we are actively seeking funding for a project that will use our current expertise on carbon dioxide capture and sequestration technology and on alternative energy options to provide a framework for selecting technologies to meet policy objectives for control of greenhouse gases.

The CEEPR has recently submitted a five-year grant proposal, led by Professor Schmalensee, to the Environmental Protection Agency, requesting support of research that will contribute to the knowledge base for future EPA policy decisions. These activities include policy research in the Joint Program on the Science and Policy of Global Change about important policy issues related to climate change.

AFFIRMATIVE ACTION

Our affirmative action achievements this year were modest. Four people were hired during the year: three secretaries and one Shophelper A. Our shophelper is a minority member.

FINANCIAL OVERVIEW

The estimated sponsored research volume for the Energy Laboratory in FY92 is $8.0 million. The distribution by research area is approximately as follows:

- Environmental/waste remediation - 21.5 percent
- Health and toxicological effects of energy use - 17.5 percent
- Combustion and fuels research - 17 percent
- Advanced energy/materials technology - 17 percent
- Transportation - 8 percent
- Nuclear Systems - 7 percent
- Energy economics, management and policy - 7 percent
- Electric power systems - 5 percent

JEFFERSON W. TESTER

Francis Bitter National Magnet Laboratory

The Francis Bitter National Magnet Laboratory (FBNML) was established in 1960, with support from the U.S. Air Force, as the first high magnetic field laboratory in the country. It continues to be the primary facility for high magnetic field research in the U.S., and operates high magnetic field facilities available, free of charge, to qualified scientists throughout the country. The Laboratory can produce a maximum dc field of 31.8 tesla (T) in a 33 mm bore, and pulsed fields up to 68 T of duration > 5 ms are available on an experimental basis. A 35 T magnet is expected to be routinely available to users in September 1992. 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.

Last year I reported how, contrary to the recommendations of the peer review process, the National Science Foundation had decided to establish the new National High Magnetic Field Laboratory (NHMFL) at Florida State University, with some pulsed field facilities to be located at Los Alamos National Laboratory in New Mexico. Practitioners of high magnetic field research were concerned that they would fall behind at a time when competing magnet laboratories in Europe and Japan were involved in major upgrades of their facilities. They felt that the NSF plan to send them to do their research at the High Magnetic Field Laboratory in Grenoble was not practical. The U.S. is now marginally ahead in the technology of high magnetic field research, and many were concerned that the NSF decision combined with the FSU intention to obtain its magnets from Grenoble would condemn the U.S. to a second class position for the foreseeable future.

In response to this situation, we prepared a proposal to the NSF requesting funds to continue to operate our dc high field facility until the autumn of 1995. We also offered to construct, in collaboration with the NHMFL, a 45 tesla class hybrid magnet to be located at the NHMFL when it is completed sometime in 1995. I am happy to report that our proposal was funded by the NSF, with a level of funding which we hope will be adequate to achieve both goals. The total NSF support for this activity is expected to be $23,000,000 over four years, and the NHMFL will provide an additional $4,000,000. This arrangement will provide the best possible support for high magnetic field research in the nation, and stabilizes the situation at the FBNML while the future of the laboratory is decided. The design work for the new hybrid is well under way, and the goal is to achieve fields of 50 tesla using the maximum 32 MW of power to be available at the NHMFL.

It has been an eventful year at the FBNML in other ways. Our 600 MHz (14 tesla) NMR magnet project has been rescued from large field inhomogeneities introduced by impurities in the stainless steel coil forms. A careful field mapping combined with sophisticated analysis enabled us to design a set of ferromagnetic shims to remove the inhomogeneities. Recent tests of the shimmed magnet on amino acid samples showed better high resolution NMR signals than can be obtained from a commercially available 500 MHz instrument. The 35 tesla hybrid recently produced a record breaking 33.5 tesla in a preliminary test. In a later test to full field, a quench of the superconducting magnet occurred. The magnet survived the quench undamaged. After some effort, the cause of the quench was identified. It can be avoided in future by a operating at a slightly reduced field, and we expect to have the system operating properly and available to users by October 1992.

Our high field magneto-optical facility has been subject to increasing demand by users across the country, and now accounts for about 15 percent of the total magnet hours. The pulsed field facility has been applied to determine the properties of superconducting fullerenes doped with alkali metals. These appear to be conventional type II superconductors and upper critical fields of 30 tesla and 54 tesla were determined for K_3C_{60} and Rb_3C_{60}, respectively. Studies of the behavior of single crystals of yttrium barium copper oxide superconductors showed that the hyteresis observed at lower fields disappears in fields above 40 tesla. Although NSF support for in-house research through the Laboratory's core grant has disappeared, the thin film superconductivity group continues to make progress. Their magnetoresistance measurements on $Nd_{2-x}Ce_xCuO_4$ provided the first defensible determination of the critical magnetic field of a cuprate superconductor.

As this report is being written, a search is underway to find a new Director for the Laboratory.

J. DAVID LITSTER

Northeast Radio Observatory Corporation/Haystack Observatory

The Haystack Observatory, located in Westford, MA, is a research center engaged in radio astronomy, geodesy, atmospheric sciences, and radar applications. The radio astronomy program is conducted under the auspices of the Northeast Radio Observatory Corporation (NEROC), a consortium of 13 educational and research institutions in the northeast[1]. The Observatory receives financial support from various federal agencies including the NSF, NASA, NOAA, and the USAF through MIT Lincoln Laboratory.

The Observatory instrumentation consists of the following facilities: a 37m-diameter radio telescope enclosed in a radome that is used for astronomical observations at wavelengths from 2.6 mm to 18 cm, an 18m-diameter radio telescope dedicated to geodetic measurements of the earth's rotation rate and plate motions using very long baseline interferometry (VLBI) techniques, two processors to correlate global VLBI experiments in astronomy and geodesy, a high-power radar that utilizes two large antennas (46 m and 67 m in diameter) to study the earth's upper atmosphere using incoherent backscatter techniques, and an optical observatory to monitor atmospheric airglow emission and measure winds in the upper atmosphere.

Highlights of the radio astronomy program in the past year include the continued development of the 37m telescope to improve its performance in the 3mm-wavelength band. The antenna surface deformations have been reduced to 0.26 mm RMS using high-resolution holographic maps that compensate for the complex diffraction effects of the radome. The goal of 0.2 mm has required improvements in the thermal environment within the radome and this will be the main emphasis of the upgrade program in the next year. In addition, a deformable subreflector has been successfully constructed during the past year and is presently undergoing extensive ground tests before installation on the antenna in late August 1992. In the electronics area, a two-channel radiometer spanning the 85-115 GHz band has been completed and has been used for observations, and a wideband spectrometer has been successfully tested at a 160 MHz bandwidth and used to process some of the spectral observations.

Key astronomical observations in the past year involved the novel detection of hydrogen cyanide (HCN) molecular line emission at 88 GHz in carbon stars, observations of silicon monoxide (SiO) masers at 86 GHz in regions of star formation in our galaxy, and the mapping of extended carbon monoxide (CO) radio emission at 115 GHz in dense molecular clouds. One of the most important recent results involved the detection of hyperfine structure in the cyanoacytelene (HC_3N) line at 36 GHz, which allowed more accurate measurements of temperature and density in dense cores that support star formation than hitherto achieved. The discovery of this new probe is expected to provide a new major thrust in the observational program at Haystack at a frequency where the telescope possesses an internationally-recognized unique capability. Other important astronomical observations involved VLBI experiments aimed at high-resolution measurements of quasar structure at 43 GHz, the first VLBI detection of the newly-discovered methanol line at 6.7 GHz, and the first VLBI observations in collaboration with the Russian radio telescope at Ussurisk and the newly-installed telescope at O'Higgins in Antarctica.

[1]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.

Technological developments for VLBI applications have proceeded along three major instrumentation initiatives. First, the main elements of high-data rate recording (1 Gbit/s) have been demonstrated in the laboratory, and two recorders are being equipped with a newly-designed formatter and additional recording heads in order to carry out the first field experiment in July 1992. This will double the sensitivity of VLBI telescopes equipped with this upgraded system. Second, a new correlator - the Mark IV, is being designed which will increase the speed of the data processing by a factor of 100 over the previous system and will yield more precise results towards the goal of 1mm precision in the baseline distance across continental separations. A new specialized computer chip is being explored for this new application. Third, the utilization of thin magnetic tape (16 micro-meter) has been tested and the recorders have been adapted to utilize it successfully. This will expand the recording time on each VLBI tape to about 12 hours at an average data rate of 100 Mbits/s. This expansion is important for the operation of the nation's Very Long Baseline Array being constructed by the National Radio Astronomy Observatory with the participation of the Haystack Observatory. The technology associated with these developments maintains Haystack as the preeminent center for VLBI instrumentation in the international community, and as in the past, the technology will be transferred to industry for production.

In our radar programs, the main highlight of the past year has been the construction by Lincoln Laboratory of a 13m-diameter antenna which will operate as an auxiliary system to the Haystack radar for near-earth satellite imaging and space debris characterization. At Millstone Hill, the new data acquisition system has been tested using coded pulses which have allowed the observations of the earth's ionosphere at a resolution of several hundred meters in altitude. The new atmospheric optical facility, constructed near the Wallace Observatory, has reached a full operational capability and is collecting data routinely on the winds and temperature of the earth's neutral atmosphere, in collaboration with the ionospheric radar which measures similar parameters in the earth's plasma. These combined measurements have been used to determine indirectly the collision cross-section of the dominant atomic oxygen species, revealing a serious discrepancy with laboratory measurements.

The Haystack educational programs have all proceeded with success. Graduate student involvement in our programs has been enhanced by the presence of several students at Haystack working on thesis projects. The summer undergraduate internship program in 1992 involves nine students working in astronomy, atmospheric sciences and instrumentation development. The Young Scholars program, aimed at pre-college level students, is continuing successfully with 30 students from the local area in a three-week summer program followed by an academic year project and special mentorship by our staff. In addition, special activities have been coordinated with the local area science teachers to enrich their curriculum and expand the exposure of their students to science and mathematics.

The staffing of the Observatory has remained fairly constant in the past year with the single addition of a digital engineer to support the design of the Mark IV VLBI correlator. Our Affirmative Action objectives continue towards recruiting women and minorities to our Observatory. Although women are well represented amongst our administrative and support staff, we wish to enhance the number of women at the scientific research staff level. We have made one offer in the past year at the post-doctoral level but have not succeeded in attracting the candidate due to a competing offer for a permanent position elsewhere. We continue to be committed to the Institute's Affirmative Action goals.

Finally, the Haystack building addition has been completed during the past year providing the Observatory with a conference facility, a library, and offices. The original building was renovated to provide much-needed laboratory space. Space for visiting astronomers was also included. Plans have been developed for testing elements of the Smithsonian Institution's submillimeter array telescope at Haystack in the next few years prior to their shipment to Hawaii.

JOSEPH E. SALAH

MIT Supercomputer Facility

MISSION

The MIT Supercomputer Facility (MITSF) became available to the MIT community in July 1989. The facility is supported by a research grant from Cray Research Incorporated (CRI) and from user fees. Our goal is to provide, through coursework and research at both the undergraduate and graduate level, education in and by the *application* of supercomputing; to combine CRI world-leading supercomputers with MIT's unique educational and computing environment to mold curricula that exploit, and advance, the frontiers of computational science. The mission fulfilled implies students that are much better versed not only in their chosen fields, but also in an advanced technology which will be increasingly critical in their future development and their professional effectiveness.

HARDWARE

The CRAY-2, which originally served the MITSF, was replaced with a Y-compatible CRAY X-MP EA/464 with a "virtual" 128 MWord Solid-State Device and 30 gigabytes of disk space. We also have "junior" (a CRAY X-MS/116) with one CPU, 16 megawords of memory, and four gigabytes of disk space.

SOFTWARE

GRAPHICS	*MATHEMATICAL*	*SIMULATION*	*COMPUTATIONAL CHEMISTRY*
X-11	EISPACK	ABAQUS	MOPAC
Curses	IMSL	ASPEN PLUS	GAMMES
GNUPLOT	LINPACK	ADINA	CHARMm
NCAR-GKS	MACSYMA	CSADIE	UNICHEM
XDS	MATLAB	FIDAP	
	NAG	HSPICE	
	SCILIB	MAPLE	
	SIMPAK	MCNP	
		NEKTON	
		SAFARI	
		TEMPEST	

THE TRANSPARENT COMPUTING MODEL

A recent addition to the educational supercomputing environment is the Transparent Computing Model (TCM). TCM is a system that provides Athena users with access to CPU cycles on the MITSF CRAY X-MP EA/464 and CRAY X-MS/116 without requiring them to have logins or permanent storage on either system. It consists of a user-extensible parser that translates local commands into their CRAY equivalents; a client program responsible for describing the user's local environment and passing signals; a server program which enforces administrative limits, recreates the user's environment, and executes the user's request; and several support programs, including a hierarchical help facility and a utility to extract usage reports. Two modes of access are possible: transparent mode, in which a user's local (Athena) file systems are NFS-mounted on the CRAY; and opaque mode, in which a temporary home directory is created on the CRAY that the user may transfer files to using the standard File Transfer Protocol (FTP) utility. Either mode allows the development of seamless (transparent) distributed applications, and either mode allows access to the "native" CRAY user interface. Currently, TCM users are restricted to using 15 minutes of CPU cycles in any 24-hour period, and eight megawords of memory. Access is restricted to Athena users via Kerberos authentication. To date, TCM has been accessed 5707 times, involving 151,975 CPU seconds, 162 users and the completion of 4468 jobs.

STAFF

The Co-Directors of the MITSF are Professors Robert A. Brown and Anthony T. Patera. The Facility is run by Administrative Officer Edward Andrews, with support from Administrative Assistant, Patric Lummuka. Technical consultation is provided by Dr. Firooz Partovi. In addition to MITSF personnel, MITSF also benefits from an on-campus CRI employee, James Purdon, provided as part of the MIT-CRI lease agreement, and MIT Information Systems (I/S) personnel provided as part of an internal MITSF-I/S Service Level Agreement. This Service Level Agreement covers all aspects of operation of the CRAY X-MP.

DEPARTMENTAL USAGE

To date the following departments have incorporated supercomputing in conjunction with coursework and research projects at the Institute: Center For Advanced Engineering, Aeronautics and Astronautics, Architecture, Biology, Brain and Cognitive Sciences, Chemical Engineering, Chemistry, Civil Engineering, Earth and Planetary Science, Economics, Electrical Engineering, Haystack Observatory, Health Sciences and Technology, Lincoln Laboratories, Laboratory for Manufacturing and Productivity , Materials Science and Engineering, Mathematics, Mechanical Engineering, Media Laboratory, National Magnet Laboratory, Nuclear Engineering, Ocean Engineering, Physics, Plasma Fusion Center, Sloan School of Business Management, Center for Space Research, Whitehead Institute, and Woods Hole Oceanographic Institute.

EDUCATIONAL USAGE

Since its inception, the MITSF is able to report supercomputing usage by 33 faculty, 55 teaching assistants, 377 undergraduate students, and 812 graduate students, for a total of 1,275 users incorporating supercomputing in coursework. The following is a partial list of courses and seminars in which supercomputing has been introduced:

Aeronautics and Astronautics

Advanced Computational Fluid Dynamics
Turbulence and Random Processes in Fluid Mechanics

Architecture

Computers and Architecture
Introduction To Building Technology

Brain And Cognitive Science

Seminar On Motor Learning

Chemical Engineering

Applied Quantum Mechanics
Gas Diffusion in Polymers
Integrated Chemical Engineering I
Numerical Methods Applied to Chemical Engineering
Structures In Properties of Matter

Civil Engineering

Advanced Structural Analysis

Electrical Engineering and Computer Science

Design and Analysis of VLSI Circuits
Design of Analog MOS LSI
Poisson Project
Simulation of Analog Circuits Using HSPICE
Solid State Circuits

Health Sciences and Technology

The Cardiovascular Simulator Project

National Magnet Laboratory

Biological and Medical Applications of Radiation and Radioisotopes

Mathematics

Topics In Applied Mathematics

Mechanical Engineering

Convective Heat and Mass Transfer
Advanced Fluid Mechanics
Conduction and Change of Phase Heat Transfer
Computational Fluid Dynamics
Computer Methods In Dynamics
Conduction and Change of Phase Heat Transfer
Convective Heat and Mass Transfer
Finite Element Applications in Mechanics and Materials
Introduction To Heat Transfer
Methods of Engineering Analysis

Theory and Practice Of Continuum Mechanics

Nuclear Engineering

Nuclear Engineering Design
Statistical Processes and Atomistic Simulations

Ocean Engineering

Analyzing the Stress Distribution of Welded Structures
Computational Geometry
Marine Hydrodynamics
Ocean Seismic-Acoustics
Panel Methods for Marine Hydrodynamics
Using the Cray to Compute Water Waves
Introduction to Naval Architecture

Physics

Computational Physics

Sloan School of Management

Security Prices/Options and Futures Markets

RESEARCH USAGE

Since its inception, the MITSF has tracked supercomputing usage of 173 faculty, 144 staff, and 410 students. Lincoln Laboratories has engaged 120 users and Woods Hole 12 users. This results in a total of 859 users for MIT- related research. Average machine utilization for fiscal year 1992 was 43%.

OUTSIDE USERS

The MITSF also provides supercomputing cycles to several commercial organizations. The following companies are current users of the CRAY X-MP EA/464:

ALLISON GAS TURBINE DIVISION
AKZO CHEMICALS
CREARE INCORPORATED
ENSR
EXA CORPORATION
GENERAL ELECTRIC
MITRE CORPORATION
NEKTONICS
RAYTHEON INCORPORATED

ANTHONY T. PATERA
ROBERT A. BROWN

Nuclear Reactor Laboratory

During the past year the Nuclear Reactor Laboratory (NRL) continued its joint interdisciplinary activities with both MIT and non-MIT collaborators: seven MIT academic departments and interdepartmental laboratories, and a number of 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, environmental studies, and nuclear medicine.

Especially noteworthy developments were the operation of the pressurized and boiling 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 has now progressed to the point where early clinical trials are envisioned.

A major project on in-pile sensors was continued with support from two Japanese companies and from the Electric Power Research Institute (EPRI). The in-pile dose and corrosion studies have evoked increased interest and have provided opportunities for major continuing research efforts. Our research in computer control of reactor power has continued to lead similar efforts in the USA.

NEUTRON BEAM TUBE RESEARCH

One of the MIT Research Reactor (MITR) beam tubes is now being utilized for prompt gamma activation analysis. The initial need is for rapid analysis of B-10 in blood and tissue. This is related to our brain cancer project. There are many additional uses for the prompt gamma facility, which we expect to use for elemental analysis on elements difficult to detect by delayed emission gamma activation analysis. A novel inexpensive system was developed at MITR-II for boron assays which rivals the capability of prompt gamma facilities installed at other United States research reactors at an expense an order of magnitude larger. Another beam tube is used, with a specially designed chopper and diffraction system, as a teaching tool for students. Measurements are made of Planck's constant and the reactor's thermal neutron spectrum as well as of various other quantities, such an total cross sections.

RADIOCHEMISTRY AND TRACE ANALYSIS

Professor Frederick A. Frey, Department of Earth, Atmospheric, and Planetary Sciences, and research colleagues, MIT graduate students, post-doctoral fellows, and visiting scientists utilize the MITR for trace element analyses of geologic materials by neutron activation analysis (NAA). Two new multi-investigator research projects have recently been initiated. They are aimed at providing an understanding of the life history of two volcanoes located in very different geologic settings – Mauna Kea, an intraplate volcano in Hawaii; and San Pedro-Tatara, an Andean volcano located in a region of plate convergence.

During 1991-92 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 Brandeis University, the University of Washington, and Clarkson University. Commercial organizations that utilized the NAA expertise of NRL during the past year were GTE, Waltham and Danvers, Massachusetts; Physical Sciences Inc., Massachusetts; Florida Power and Light; the Empire State Electric Energy Research Corporation (ESEERCO); and EPRI.

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. Concentration of chlorine in chemotherapeutic agent loaded biodegradable polymers and sodium in biocompatible and biodegradable polymers were determined for Professor Robert Langer and his group (Chemical and Biochemical Engineering). Toxic metals in sediments were analyzed for Professors William G. Thilly and Harold F. Hemond (Center for Environmental Health Sciences and Civil Engineering, respectively). Impurities in aluminum were analyzed for Dr. Kwan S. Kwok (Nuclear Reactor Laboratory). Nd/Ce ratios were determined for Professor John M. Graybeal (Department of Physics).

Dr. Olmez has been actively engaged in a number of environmental research projects. Financial support has been continued by the Environmental Protection Agency (EPA) for the investigation of the possibility of using rare earth elements as markers for motor vehicle emissions. A three-year $500,000 grant which was obtained from the Empire State Electric Energy Research Corporation to study the current toxic metal levels in atmospheric particulate materials and wet deposition

in upstate New York continued. Additional support has been obtained from EPA to allow continued participation in the ongoing Great Lakes project.

Funding was obtained in the past year for two new projects: the first is for the study of the fate of mercury in the environment (ESEERCO, $600,000/three years), and the second is related to bioturbation studies in sediments (US Geological Survey, $50,000/year).

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 is engaged in 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 fifth year with good progress on all tasks. Last year an outside review committee gave the joint MIT–Tufts New England Medical Center project high grades for performance during its first three years. This year positive reviews were again received when, as part of the preparation for patient trials, MIT hosted an International Workshop on Neutron Beam Dosimetry. Preparation for the first human clinical trials is currently a central activity of this project.

The MIT Reactor also supports nuclear medicine programs conducted by several hospital and radiopharmaceutical groups outside MIT. A summary of these activities is provided in a following section.

RADIATION HEALTH PHYSICS

The NRL supports a 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. 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 and Dr. Kwan S. Kwok of the NRL and Professor David D. Lanning, Nuclear Engineering Department, continued studies on the closed-loop, digital control of nuclear reactors during both steady-state and transient operation. Assistance was received from Professors Allan F. Henry and John E. Meyer (NED). A general set of control principles, based on reactivity constraints and intended for nonlinear conditions, was deduced and experimentally demonstrated on the MIT Reactor during 1983-1985. This approach is unique in that it is based on the general equations of reactor dynamics rather than on measurements of specific response characteristics. The 'reactivity constraint approach' was licensed by the United States Nuclear Regulatory Commission (NRC) for general use on the 5 MW MIT Research Reactor in April 1985. As a result, closed-loop control experiments can be performed without *à priori* restrictions on the associated reactivity. Among the concepts developed and experimentally tested on the MIT Research Reactor have been a rule-based controller, an on-line method for control law reconfiguration, period-generated control laws, model-based methods including feedforward control, and automated startup technologies. Present efforts include an experimental evaluation of flux synthesis methods for reactivity estimation, control in the presence of positive feedback, and control of reactors in spacecraft intended for the exploration of Mars. This work is currently supported by the United States Department of Energy and by the Sandia National Laboratories (SNL). It has resulted in 16 publications during the past year. In addition, five major reports summarizing both the theoretical and experimental work performed in this area have now been issued. One N.E. and two Ph.D. degrees were granted during the past year for research performed on this project. There are currently two S.M. 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

Several major interdisciplinary and interdepartmental research programs designed to develop radiation dose reduction technology for the nuclear power industry are in progress. They are currently supported by a consortium of US and Japanese nuclear industry sponsors. Funding at the level of about $1 million per year is available to support this work. Radiation fields in the primary coolant system of today's light water reactors are undesirable from a health viewpoint and have a significant negative impact on plant capacity factors by impeding maintenance tasks. The principal goal of the project is to reduce the radiation fields to which workers are exposed. Studies of how these fields are built up and methods for minimizing them are being conducted with the aid of small-scale coolant circulation loops installed in the core of the MIT Reactor, designed to simulate (in separate loops) conditions that exist both in pressurized-water reactors and in boiling-water reactors. The formation, transport, and deposition of corrosion products in the coolant is being characterized, and tests are under way to obtain information about optimized water chemistry, surface treatments, and other parameters. Principal investigators are Professor Otto K. Harling (NRL), Professor Emeritus Michael J. Driscoll (NED), and Dr. Gordon E. Kohse (NRL). Others also participating are Dr. Ilhan Olmez, of NRL; members of the MIT Reactor staff; Professors Ronald G. Ballinger and David D. Lanning of NED; Dr. William Lindsay, an expert consultant in the field of reactor coolant corrosion studies; and a growing number of MIT students from the Nuclear Engineering Department. Three utilities – Public Service Electric & Gas, Northeast Utilities, and Boston Edison Co. – have provided additional financial support. These projects utilize the MIT Reactor directly and provide much needed support for experimental research in nuclear engineering. It is expected that two to four graduate students will continue to be involved in this project.

Support for future research in these areas has been obtained for studies with an in-pile loop which simulates boiling water reactor conditions. Sponsors are General Electric, the Electric Power Research Institute, Hitachi, and Toshiba.

IRRADIATION–ASSISTED STRESS CORROSION CRACKING

Another project based on the technology in our loop project started in September of 1988 with support from the Electric Power Research Institute and the Tokyo Electric Power Company. This four-year project, supported at the $600,000/year level, addresses some of the issues associated with irradiation-assisted stress corrosion cracking (IASCC). Extended reactor usage and lifetime prolongations have raised the issue of IASCC in light water power reactors (LWRs) to a high priority. The expertise which we already have in in-pile testing under LWR conditions and our experience in stress corrosion cracking (Professor Ronald G. Ballinger) and nuclear materials testing (Professor Otto K. Harling) were combined to develop a successful proposal for this long-range intellectually stimulating project. An extension of this project for two years is likely, and a five-year follow-on project is in the planning phase with the sponsors.

SENSOR PROJECT

The Sensor project is a continuing program complementary to the IASCC project described above. It is a two-and-a-half-year project funded at approximately $500,000/year by the Electric Power Research Institute, Hitachi, and Toshiba. Principal investigators are Professor Ronald G. Ballinger and Dr. Gordon E. Kohse, with support from the Dose Reduction and IASCC staff.

Instrumented crack sensors and electrochemical potential sensors will be operated under simulated BWR conditions in the MITR-II core. The primary objective of the research is to demonstrate the effectiveness of hydrogen water chemistry in controlling irradiation-assisted stress corrosion cracking. This research will also contribute to a more general understanding of important IASCC variables: material composition and processing; water chemistry, including radiolysis chemistry; and irradiation damage.

REACTOR IRRADIATIONS AND SERVICES FOR RESEARCH GROUPS OUTSIDE MIT

In nuclear medicine, the development and/or continuing production of radioisotopes for use by researchers at hospitals and other universities included: 1) production of Au-198 seeds for Dr. Philip Cobb of the New England Deaconess Hospital for use there for cancer therapy; 2) production of Dy-165 for Dr. Clement B. Sledge of Brigham and Women's Hospital for research studies in the treatment of arthritis; 3) 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 4) investigations by Dr. McDonald Wrenn of the University of Utah using track etching techniques to determine the lower detection limit of uranium in water.

In a number of other areas, also, reactor irradiations and services were performed for research groups outside MIT. Most of these represent 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) Dr. Mike Kitto, New York Department of Public Health, used neutron activation analysis for environmental studies; 3) Dr. Alan P. Fleer of Woods Hole Oceanographic Institute used irradiation to determine natural actinides and plutonium in marine sediments; 4) 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 1163 students and 248 faculty and staff from over 77 other educational institutions benefited from visits to and use of the MITR during the past year. Popularity of the sharing program continues to grow.

Research utilization of the MITR by other institutions under the Reactor Sharing Program during the past year has included: 1) use by Professors J. Christopher Hepburn and Rudolph Hon of Boston College to activate geological specimens and standards for the NAA of rare earth and other trace elements in studies of the geological development of the northeastern United States; 2) neutron activation analyses of ice cores for the State University of New York, Buffalo; 3) gamma irradiation of plant seeds for several area high school students participating in science fair projects; 4) research to identify elements other than lead from motor vehicle emissions in collaboration with Professor G. E. Gordon, University of Maryland; 5) food, water, and soil analyses from Rota Island, Forsyth Dental Center; 6) measurements of boron concentration and work on high resolution track etch autoradiography for Professor Robert Zamenhof of Tufts–New England Medical Center; 7) neutron activation analysis studies of protein-fractionated human parotid saliva by Georgetown Medical Center; 8) a study of the effects of oil-well fires in the atmosphere of Kuwait and Saudi Arabia, by Professor J. Spengler, Harvard School of Public Health; 9) the study of elemental depth profiles in sediments by Professor D. Ryan of the University of Lowell; 10) participation in several special high school student projects; and 11) neutron activation analysis of subsurface water supplies by Fairfield University.

For education of the general public and students at all levels in local and other New England schools, the reactor staff provides lectures and tours periodically throughout the year. Several local universities incorporated reactor visits and experiments into their regular course curricula, as follows: 1) Northeastern University, Physics Department, Course PHY 1555, 10 students, 2 visits; 2) the University of Massachusetts, Harbor Campus, Professor Martin Posner, Department of Physics, Physics 603, 30 students, 4 visits; and 3) Bates College, Department of Physics, Professor John Smedley, 10 students, 1 visit.

An educational program to familiarize high school science teachers with the scientific, engineering, and medical uses of nuclear research reactors and to involve the teachers in typical applications and experiments, with a special lecture and demonstration by the MIT Radiation Protection Office, is also funded by the USDOE Reactor Sharing Program. Three seminars of four and one-half hours each were held in the spring. The attendance for this year was 25 teachers and 35 students.

AFFIRMATIVE ACTION

The NRL supports the affirmative action goals of the Massachusetts Institute of Technology. Of a staff of 35 there are currently five engineering and management positions held by minorities and women. The NRL participated in the USDOEs program for minority training in reactor operations, and one of our current senior reactor operators is a graduate of this program.

MIT RESEARCH REACTOR

The MIT Reactor completed its 34th year of operation, its 18th since the 1974-75 shutdown for upgrading and overhaul. The reactor normally operates on a Monday through Friday schedule. However, for the past year the reactor operated continuously (seven days per week) during much of the second half of 1991 to support several major experiments related to the dose reduction studies. Also, much low power testing was performed for the neutron capture therapy program. On average, the MIT Reactor was operated 80 hours per week with 75 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 288,711 megawatt-hours at June 30, 1992. The MITR-I generated 250,445 in the sixteen years from 1958 to 1974.

To summarize briefly the reactor utilization described in more detail above, it was well utilized during the year, although still more experiments and irradiations can be accommodated due to the number and versatility of its many facilities. The reactor, as an integrated whole, continues to be used in a series of experiments designed to demonstrate the feasibility and advantages of reactor control by digital computer. Two pressurized loops for a major interdepartmental project on dose reduction for power reactors are installed in the reactor. A major project on irradiation-assisted stress corrosion cracking, initiated with United States and Japanese support, is progressing. A new large project involving in-pile sensor testing continues with domestic and foreign support. The number of specimen irradiations was 1188. There were 58 irradiations in the medical room, most in support of the neutron capture therapy program for the treatment of brain cancer and subcutaneous melanoma. Theses and publications on research supported by the reactor are running at about 20 and 50 per year, respectively. A total of 1624 people toured the MIT Research Reactor during 1991.

There is an increasing need in the world for irradiation space for neutron transmutation doping of silicon crystals. A project is being initiated for the neutron transmutation doping of single crystal silicon ingots in one of the reactor's horizontal throughports. Thus far, physics and engineering studies have been performed to characterize the neutron beam and to determine the feasibility of uniformly irradiating the ingots with simultaneous translational motion over an interval of several days through the beam port. These measurements and design studies are currently being done by the MITR staff and it is expected that the effort will provide support and research topics for several graduate students. If successful, the result of this project should provide a source of base support to the reactor.

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.

Dr. John A. Bernard, Director of Reactor Operations, completed his term as Chairman of the National Organization of Test, Research, and Training Reactors. This organization provides a forum for research reactor managers to discuss regulatory and operational issues. The NRL hosted the annual meeting of this organization in October 1991.

OTTO K. HARLING

Operations Research Center

INTRODUCTION

The Operations Research Center (ORC), established in 1953 as an interdepartmental graduate degree program, completed its 39th year of continuous operation in 1991-92. The year was marked by the continued success of the center's educational programs coupled with another significant increase in its research activities and with continued planning for future development.

Highlights of the year included: continuing excellence of our academic programs as reflected by the largest applicant pool in the history of the ORC; a wide variety of methodological and applied research projects and an increase in the research volume at the ORC; a major redesign of the ORC doctoral examination structure; continuing efforts on expanding the center's outreach; and a large number of individual distinctions for our students and affiliated faculty and staff. This report provides some details on these 1991-92 activities and reviews briefly the ORC and its educational and research programs.

FACULTY, STUDENTS, STAFF

Richard C. Larson, Professor of Electrical Engineering, was appointed as one of the Codirectors of the ORC. Thomas L. Magnanti, George Eastman Professor of Management Science, continued in his role as Codirector at the center.

This year the ORC had 33 affiliated faculty and senior staff. Faculty are drawn from the School of Management and the Departments of Electrical Engineering and Computer Science, Civil Engineering, Ocean Engineering, Mathematics, Aeronautics and Astronautics, Mechanical Engineering, Urban Studies and Planning, and Nuclear Engineering.

The Operations Research Center offers two interdepartmental graduate degree programs, one leading to a Ph.D. degree in Operations Research and the second leading to a master's degree. During 1991-92, these programs enrolled 51 students--33 Ph.D. candidates and 18 S.M. candidates. The center conferred 13 master's degrees and 11 Ph.D.'s in operations research. Several other Ph.D. theses were in the final stages of completion in the summer of 1992, and the center will award two more Ph.D. degrees by September 1992.

For the fall term 1992, the ORC expects an incoming class of 19 students, carefully selected from the largest pool of applicants in the center's history (120 total).

Affirmative Action

The ORC is proud of its accomplishments in the area of equal opportunity. Its primary support staff comprising two administrative assistants and one administrative officer are all women, with one being African American. In the graduate student population, women are regularly well represented with typically 30% of our students being women. An incoming master's candidate is an African American male with impressive credentials. Improvement is needed in the area of MIT's OR-affiliated faculty members who are women and/or representatives of hitherto under-represented minorities.

ACADEMIC PROGRAMS

The ORC's academic programs continue to be recognized as ranking among the very best nationally and internationally. Our program, moreover, is repeatedly cited as achieving an excellent balance between applications and methodology.

In view of constraints imposed by our limited financial and space resources, we have determined that the size of our Ph.D. program cannot increase any further over the foreseeable future. In dealing with our space constraints, during the past year the ORC underwent a major relocation and renovation process. The purpose of the relocation was to bring together the ORC and the Statistics Center at MIT into a single consolidated space; in addition, this newly renovated space will house the new Decision Sciences Program.

Based upon the recommendations of a very productive faculty/student committee, the center instituted major changes in its doctoral examination structure in the 1991-92 academic year. Ph.D. students are now required to take the Qualifying Examination after they have completed two semesters at MIT. The exam is administered in September of the student's second year. The redesign of the General Exam was more dramatic than that of the Qualifying Exam. The written exam has been replaced with a subject requirements list, the critical review paper has been replaced by a research-oriented paper, and the oral examination has become much more extensive.

RESEARCH ACTIVITIES

During 1991-92, the volume of research conducted directly through the ORC grew significantly again for the fourth consecutive year. This work, nonetheless, represents but a small fraction of OR-related research carried out throughout the Institute by ORC-affiliated faculty and staff. Research activities spanned a wide spectrum of methodological topics and applications and ranged from small, unsponsored projects involving a single faculty supervising a student's thesis to much larger, sponsored programs involving several faculty/staff and students.

Examples of primarily methodological research topics include work on: mathematical programming and combinatorial optimization, including modeling languages and solution methods for integer programming, projective transformation methods for linear programming, and cluster analysis; parallel and distributed computation and algorithms; network flow algorithms; network optimization and network design; probabilistic combinatorial optimization problems - a new class of very interesting probabilistic variations of standard combinatorial optimization problems; facility location in both deterministic and stochastic settings; queueing theory under both static and dynamic conditions; quantifying the equitability of queueing systems; analysis of queueing networks; stochastic processes; classical and Bayesian statistics; and decision analysis and statistical decision theory.

ORC faculty are also currently investigating several major areas of application including: flexible manufacturing systems; financial services; marketing; transportation systems; air traffic control; public services, such as urban emergency systems; criminal justice; safety and risk analysis in air transportation, communication systems, nuclear engineering and epidemiology; remotely controlled queueing systems; and industrial production and transportation logistics.

Several organizations sponsored research projects at the ORC during 1991-92, for example: the National Science Foundation (several projects); the C.S. Draper Laboratory (several projects and Draper Fellowships); National Institute of Justice, the Department of Transportation (several projects); the Federal Aviation Administration; the Air Force Office of Scientific Research; AT&T; Commonwealth Electric; IBM; and United Parcel Service Foundation.

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 1992.

In April 1992, ORC faculty, in cooperation with the Center for Transportation Studies, presented a one-day symposium on "The Use of Transactional Data in Transportation and Other Services Industries." Six MIT faculty (including David Litster, Vice-President and Dean of Research), representatives from Princeton Transportation Consulting Group, Draper Laboratory, and Burlington Northern Railroad gave presentations on topics that reflect the cutting edge of current research on the use of transactional data. Approximately 34 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 Sunil Chopra and Mark Daskin, Northwestern University; Ellis Johnson, IBM and Georgia Institute of Technology; Michael Magazine, University of Waterloo; Edward Kaplan and Eric Denardo, Yale University; Stephen Pollock, University of Michigan; Yves Dallery, Universite Pierre et Marie Curie (France); and Donald Morrison, UCLA.

HONORS AND AWARDS

A number of ORC-affiliated faculty, students and alumni received noteworthy distinctions during 1991-92 as well as continued to serve in important editorial capacities of the top professional journals in OR and management science.

Professor Richard C. Larson was elected to the position of President of the Operations Research Society of America (ORSA). In addition, Professor Larson received an Honorable Mention for the TIMS Franz Edelman Award for his work with reducing delays in the New York City arrest and arraignment system. Professor Thomas L. Magnanti was awarded the Gordon Y Billard Award for special service of outstanding merit performed for the Institute, as well as being named the Class of 1960 Fellow for a period of two years. John C.D. Little received the Paul D. Converse Award of the American Marketing Association for outstanding contributions to the science of marketing for his article, "Models and Managers: The Concept of a Decision Calculus."

Philippe Chevalier (thesis supervised by Larry Wein) was runner-up for the 1991-92 George E. Nicholson student paper competition. Robert Shumsky received the Harold L. Hazen Award from EECS for his outstanding teaching abilities. Richard Staats published the cover story for *OR/MS Today,* December 1991 issue. S. Raghavan was awarded the Martin Farber Bell Laboratory Fellowship for the Summer of 1992 and Zhihang Chi (thesis supervised by Robert Simpson) received the William E. Jackson Award by RTCA for his Master's thesis.

The ORC alumni received the following distinctions: Kalyan Talluri (thesis supervised by Thomas Magnanti) received honorable mention for the Sloan School's Zenon S. and Clotilde Zannetos Ph.D. Thesis Prize; Edward Kaplan was the recipient of the TIMS Franz Edelman Award.

THOMAS L. MAGNANTI
RICHARD C. LARSON
Codirectors

Plasma Fusion Center

The primary objective of the Plasma Fusion Center is to develop a basic understanding of the behavior of plasmas, and to exploit that knowledge by developing useful applications involving the plasma medium. The most important potential application is the development of fusion power; however, as can be appreciated by scanning the research highlights presented below, applications involving this ubiquitous state of matter are numerous and diverse. This richness of a field which is so deep and intellectually challenging, and yet possesses so many 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 laboratories involved in the physics and engineering aspects of magnetic confinement fusion and plasma research. Its research programs produce significant results on several fronts: (a) experimental confinement research on the Alcator C-MOD tokamak (investigations of the stability, heating, and transport properties of plasmas at high densities, temperatures and magnetic fields), and similar collaborative efforts on other tokamaks in the United States and Europe, (b) the basic physics of energetic plasmas (plasma theory, RF heating, nonneutral plasmas and coherent EM wave generation, development of high-temperature plasma diagnostics, and basic plasma experiments on the Versator II and Versatile Toroidal Facility tokamaks), and (c) a broad program of technology and engineering development (e.g., magnet systems, superconducting materials, fusion environmental and safety studies, advanced millimeter-wave sources, system studies of fusion reactors including operational and technological requirements, and plasma waste-treatment systems).

The Plasma Fusion Center technical programs are supported principally by the Department of Energy's Office of Fusion Energy. There are approximately 315 personnel associated with PFC research activities. These include: 24 faculty and senior academic staff, 76 graduate students and 35 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; 93 research scientists and engineers and 43 visiting scientists; 32 technical support personnel; and 36 administrative and support staff.

Last year's report described the impact of shifting priorities and diminishing budgets on the national effort to develop fusion energy. Despite strong support from the Department of Energy's Fusion Policy Advisory Committee, as well as from the Secretary of Energy, the total fusion program budget continues to decline. As a consequence, the Burning Plasma Experiment (BPX), which was to be the world's first ignited or near-ignited fusion experiment, and which was in an advanced state of conceptual design at the time last year's report was written, was cancelled last fall. This leaves the International Thermonuclear Experimental Reactor (ITER) as the main vehicle for advancing fusion energy research into the regime of ignited, or self-sustained, plasmas. Since the costs of design and construction of ITER will be shared among the four participants - the U.S., Europe, Japan, and Russia - the cost to the U.S. will be significantly less than it would be had the U.S. chosen to undertake a comparable device alone. However, the loss of a major experimental facility such as BPX will significantly weaken the U.S. national effort and has implications for MIT and the other major participants in the national fusion program.

In particular, Alcator C-MOD, the Plasma Fusion Center's new high-field tokamak which began operation last year, was originally conceived mainly as a prototype of the BPX. Consequently, cancellation of the BPX has caused a reevaluation of the role of Alcator C-MOD and its purpose as a major element in the national program. Fortunately, Alcator C-MOD was designed with the capability to address a much broader range of issues than those specifically needing resolution for the design and operation of BPX. Hence, we have had little difficulty in reorienting the goals of the Alcator C-MOD research program to better address ITER-relevant issues, as well as those issues affecting the design of an advanced tokamak fusion reactor. A particularly difficult problem for ITER is the design of a divertor, or heat removal system, which will exhaust several hundred megawatts of thermal power, while limiting the maximum heat load on a material surface to about 10 MW/m^2. Alcator C-MOD has an advanced divertor design which is unique among presently operating tokamak experiments, and which incorporates many of the key elements in the present ITER design approach. Thus, the physics of particle and power exhaust, which are crucial issues for the design of ITER and fusion reactors, have become high priority elements in the Alcator C-MOD research program.

Beyond Alcator C-MOD, PFC programs support ITER in critical technology areas, including superconducting magnets and development of millimeter wave RF sources suitable for heating and driving current near the electron gyrofrequency. In the magnetics area, D. Bruce Montgomery, Associate Director for the Fusion Engineering and Technology Division, leads the US ITER magnetics effort. The PFC will therefore play a key role in what will be an extensive, internationally coordinated program of superconducting magnet development leading to construction of magnets at a scale and performance level well beyond that of present-day superconducting magnet experience.

At the present time, the international effort on ITER is moving from the conceptual design phase, which was completed at the end of CY 1990, to an engineering design phase which is likely to begin during the fall of 1992. The objectives of this phase, which is referred to as the Engineering Design Activity (EDA), are to produce an engineering design for the ITER reactor and to carry out the R&D necessary to support the main design approach. An interesting and challenging facet of the EDA is that the design work will be done simultaneously at three co-centers located in Garching-bei-München (Germany), Naka (Japan), and San Diego (USA). The Garching site is responsible for in-vessel components (vacuum vessel, divertor, blanket and shield, RF heating), the Naka site is responsible for ex-vessel components (magnets, power systems, plant) and the San Diego site has responsibility for design integration. PFC personnel are expected to take on key responsibilities at these sites. In particular, the PFC Director, Ronald R. Parker, has been nominated to head the design team at Garching and Richard J. Thome, Head of the Fusion Technology and Engineering Division, has been nominated to head the magnetics design work at Naka. Confirmation of these nominations awaits formal signing of the EDA agreement by the four parties, an event which is expected to occur by the end of summer 1992.

With this as background, we turn our attention to highlights of the past year's research. The remainder of the report is organized to correspond to the six PFC Divisions: Toroidal Confinement, Fusion Technology and Engineering, Physics Research, Fusion Systems, and Coherent Electromagnetic Wave Generation, and Relativistic Electronics.

TOROIDAL CONFINEMENT DIVISION

The toroidal confinement division, led by Ian Hutchinson, consists primarily of the Alcator group, which is carrying out experimental research on high-field, high-performance tokamaks. The new device, Alcator C-MOD, first came into operation in October, 1991.

The purpose of the Alcator C-MOD program is to address a range of critical issues confronting the development of the tokamak as a viable fusion reactor concept. These issues include power and particle handling, control, enhanced transport, and RF heating and current drive. The high magnetic field (9T) and strong shaping ($\kappa \approx 1.8$) of Alcator C-MOD result in plasma currents up to 3MA, projecting to plasma performance comparable to the best so far achieved in any tokamak. The state of the art plasma diagnostic complement and ample port access combine with the unique characteristics associated with the high particle-, power-, and current- densities of this relatively small size device to position Alcator C-MOD as a premier research facility in the world tokamak program.

The activities within this Division are organized into four principal Sections: Operations (Steve Fairfax), Plasmas (Steve Wolfe), Experiments (Earl Marmar), and RF Heating (Miklos Porkolab). Highlights of the recent technical progress made by each of these groups are presented below.

Operations Section

This group is responsible for design and fabrication of the tokamak facility as well as its operation, maintenance, and upgrade. Steve Fairfax heads this Section, with assistance from David Gwinn (Project Engineer), Frank Silva (Operations Supervisor), Catherine Fiore (Project Safety), and others.

The tokamak and its associated power and control systems were fully assembled during the last year and operated without cryogenic cooling for the first time in September and October, 1991. These integrated systems tests were successful and culminated with plasma initiation. The cryogenic cooling systems were installed during the winter months and operations resumed in March, 1992. Plasma initiation was re-established in early April and attempts to raise the plasma current were begun. Unfortunately, one of the poloidal field tokamak magnets suffered a structural failure during the spring operating campaign. All protection systems

operated properly and there was minimal consequential damage despite the release of over 300 kJ in the fault. The machine was subsequently warmed to room temperature and disassembled. A flaw in the design of the coil termination was discovered, and the problem eliminated by relatively minor redesign. The machine will soon be re-assembled and plasma operations are scheduled to begin again in the fall of 1992.

The testing of the power conversion and control systems will continue throughout this period. Over 700 MVA of power conversion equipment has been installed and tested. A complex of several dozen personal computers and programmable logic controllers, linked by fiber optics, will be expanded and the software upgraded during the coming months. The hybrid analog/digital plasma control computer operated successfully during the April operations. The operator interface for this critical apparatus will be upgraded prior to resuming operations.

Plasma Section

The Plasma Section is involved in advancing the understanding of the tokamak configuration in the areas of transport (sub-group headed by Martin Greenwald) and MHD physics (Robert Granetz), as well as for developing and implementing optimized control procedures for tokamak operation.

The magnetics diagnostic system, which measures magnetic fields, fluxes, and currents inside the tokamak, worked exceedingly well during the initial plasma campaigns. The magnetics measurements, coupled with analysis software to reconstruct the evolution of the vacuum flux structure inside the vessel, were crucial to achieving the poloidal field null and timing necessary to get plasma breakdown. As expected, very large eddy currents (of order 0.5 MA) circulate in the axisymmetric machine structure. Control of the field structure at the mTesla level was found to be important for breakdown and plasma current initiation. The ability to diagnose the field null and achieve breakdown under these conditions verifies the design of the magnetics diagnostic system.

A novel digital-analog hybrid control system, developed in collaboration with the CRPP of Ecole Polytechnique Federale de Lausanne (Suisse), was used for power system control (in the feed-forward mode) during the spring operating campaign. Implementation of the full feedback capability was imminent at the time of the coil failure.

Experiments Section

This group focuses on studies of edge plasma physics (Bruce Lipschultz), advanced plasma diagnostics (James Irby), and other experimental techniques for understanding and improving plasma performance.

The initial operation of the tokamak has been accompanied by the first opportunities to perform plasma measurements on C-MOD. Systems which have already been commissioned include: multi-chord, 2 color interferometer for density profiles (J. Irby); magnetic diagnostics, for field null, plasma current, and equilibrium configuration (R. Granetz); visible spectroscopy, for hydrogen recycling and impurity measurements (J. Terry); X-ray spectroscopy, for electron temperature (J. Rice); neutron detectors (C. Fiore, R. Boivin); bolometer array for total radiated power (J. Goetz); thermocouple arrays, for first wall temperature and power loading (B. LaBombard); and X-ray tomography arrays (R. Granetz). Systems which will be ready for operation within the next few months include: two dimensional multi-pulse Thomson scattering for electron temperature and density profiles (J. Casey); electron cyclotron emission interferometer for electron temperature profiles (A. Hubbard); high resolution X-ray spectroscopy for ion temperature profiles (J. Rice); multi-channel reflectometer, for electron density profiles and fluctuations (J. Irby); fast neutral particle energy analyzers, for ion temperature (R. Boivin); vacuum ultra-violet spectroscopy, for impurity measurements (J. Terry); Langmuir probe arrays, for edge density and temperature (B. LaBombard); edge neutral pressure gauges (B. Lipschultz); and CO_2 laser scattering for fluctuation and RF wave measurements (Y. Takase).

An important component of our diagnostic development efforts includes collaboration with groups outside of MIT. Included among these are collaborations with: University of Maryland, on visible/UV spectroscopy (H. Griem, J. Moreno); Johns Hopkins University on EUV spectroscopy (M. Finkenthal, H.W. Moos); Lawrence Livermore National Laboratory on ECE grating spectroscopy; ENEA, Frascati, Italy, on X-ray spectroscopy (F. Bombarda); and Princeton Plasma Physics Laboratory on impurity pellet diagnostics.

RF Heating Section
This group has responsibility for the implementation and analysis of plasma heating using radio frequency (RF) power. Key physicists are Yuichi Takase and Stephen Golovato.

RF heating requires high power RF to be generated, transmitted to the tokamak, launched into the plasma, and absorbed by it. Successful RF heating will bring the C-MOD plasma to temperatures of 4-8 keV, well in excess of those obtainable by Ohmic heating alone. During the past year significant effort has been spent on designing the antennas and transmission line components, and on upgrading the transmitters.

The present RF transmitters operate at a frequency of 80 MHz (corresponding to the gyroresonance of ^{3}He at 8.1 T), and will consist of four 2.0 MW RF sources. Two of these transmitters are being upgraded to long pulse operation (1 s pulse length), and installed in the Nabisco Laboratory. The upgrade of the first transmitter has been completed and high power tests are ongoing. To date a maximum power of 1.7 MW has been achieved, and we expect that the 2.0 MW target value should be achievable. The second transmitter will be upgraded by the summer of 1993, as needed. The first antenna (single strap, movable) for coupling the power to the plasma has been fabricated and is ready for installation. At present this antenna is in a test stand and high RF power is being applied to it to evaluate its high voltage capabilities. The test results so far have been satisfactory. Two additional antennas, each consisting of two current straps, capable of more flexible phasing and higher power handling, are under construction. These antennas will be completed by the end of this year.

FUSION TECHNOLOGY AND ENGINEERING DIVISION
The Fusion Technology and Engineering Division reports to D. Bruce Montgomery, Associate Director for Technology and Engineering, and is led by R. J. Thome (Head) and J. V. Minervini (Associate Head). The Division provides engineering analysis for advanced projects centered around magnetic systems, and carries out research and development for those applications. In 1991-1992 funding for Division projects was split between fusion (45%) and other programs (55%). It is anticipated that the percentage of effort in fusion technology and engineering will increase in future years.

The largest fusion activity (≈ 52% of the fusion work) in 1991-92 was related to R&D for the ITER post-conceptual design program. D. B. Montgomery serves as head of the US ITER Magnetics R&D Program. This multidisciplinary activity is focussed on the development of niobium-tin conductor and the design and test of appropriate model coils to ensure the reliability of the ITER magnet systems when they are built. These coils will be the largest magnetic structures ever to be manufactured and the future of fusion as an acceptable energy technology hinges in large measure on ITER reliability and availability. The coils for ITER require radiation-resistant materials, especially steels and insulations. The Division works together with the Department of Material Science and Engineering in this development work, as well as with other US laboratories and universities including Lawrence Livermore, Lawrence Berkeley, Oak Ridge, the National Institute of Standards and Technology, the University of Wisconsin and Florida State University. The in-house work is headed by J. V. Minervini and M. M. Steeves.

The 1990-91 Report to the President referred to the Burning Plasma Experiment and work at the PFC on its poloidal field coils. In October 1991 the Department of Energy cancelled this program and charged the fusion community to develop a national plan for a smaller, less-expensive next-step tokamak. The Technology and Engineering Division has played a major role in this program (48% of the fusion effort) in providing magnet design support to various US community groups developing device designs. In addition the Division has played a key role in the design of the SSAT-S tokamak, a small superconducting machine that meets DOE criteria and will advance both technology and physics requirements for fusion reactors. This device will be the choice of the national program. Funding is anticipated to continue at the present level. J. H. Schultz has had principal responsibility for this undertaking.

The single largest program in the Division in FY91-92 (≈ 33% of total effort) has been work for the Superconducting Super Collider Laboratory (SSCL). This work has included the design, development and test of the interconnect bus that will ultimately connect the almost 10,000 dipole and quadrupole magnets that comprise the SSC main ring. The bus has been taken into production for use in the SSC "String Test" in which a number of magnets will be tested under expected normal system operating conditions.

Work for the SSCL has also included the design of the magnet system for the GEM (γ, electron, μ) detector, the second of the very large detectors (18 m bore x 31 m overall length). This work has involved development of a new superconductor design and the associated conductor development, as well as design of the balance of the cold mass components. This work will continue in 1992-93 at equal or greater funding. P. G. Marston and B. A. Smith have principal responsibility for this project.

Magnetically levitated high-speed vehicles were projected as a growth area in the 1990-91 President's Report. At present about 17% of the division's funding comes from maglev work. Most of this is from the Army Corps of Engineers to participate in the conceptual design of a maglev system for the U.S. This work is done under Magneplane International, and involves collaboration with Lincoln Laboratory (M. Judd and C. Haldeman) as well as with major industrial partners including Raytheon, United Engineers, and Beech Aircraft. In addition, the division collaborates with Professor Thornton of the Department of Electrical Engineering in a similar project headed by Bechtel. R. J. Thome heads the maglev effort.

PHYSICS RESEARCH DIVISION

The primary objective of the Plasma Fusion Center's Physics Research Division, headed by Miklos Porkolab, is to develop a basic experimental and theoretical understanding of plasma properties. Present physics research activities in the division include the following: experimental research on the Versator II tokamak, which will be terminated in 1992 (Miklos Porkolab and Ronald Parker); the Versatile Toroidal Facility or VTF (Ronald Parker, acting head); collaboration on the PBX-M tokamak at the Princeton Plasma Physics Laboratory and the JET tokamak at Culham, England (Stanley Luckhardt, Jay Kesner and Paul Woskov); fusion theory and computations (Abraham Bers, Thomas Dupree, Jeffrey Freidberg, Jay Kesner, Kim Molvig, Jesus Ramos, and Dieter Sigmar); theory of thermonuclear plasmas (Bruno Coppi); RF interactions and modelling (Paul Bonoli, Ron Englade, Stefano Migliuolo and Miklos Porkolab); ionospheric plasma research (Min-Chang Lee); x-ray, γ-ray and Fusion Products Diagnostics (Richard Petrasso); small scale turbulence and chaos (Paul Linsay and George Johnson); development of phase contrast imaging diagnostics on the DIII-D tokamak in San Diego (Stefano Coda and Miklos Porkolab). Highlights of progress made during the past year in selected physics research areas are summarized below.

Versator II Research Program

Versator-II is a medium-sized research tokamak (the oldest in the US, with major radius R = 40.5 cm, minor radius a = 13 cm, toroidal magnetic field B = 1.5 T) with primary emphasis on basic investigations of radio-frequency (RF) plasma interactions, including heating and non-inductive current drive, studies of plasma stability and development of novel diagnostics. Experiments on Versator II during the past year have focused on completing three Ph.D. thesis projects, including studies of: (a) Launching the "fast-branch" of lower hybrid waves at a frequency of f = 800 MHz using innovative dielectric-loaded waveguide array couplers, and observing the "synergistic" interaction of such waves with a suprathermal electron distribution created by a "slow" lower hybrid wave at a frequency of f = 2.45 GHz; (b) electron cyclotron heating (ECRH) and plasma startup experiments using a 200 kW gyrotron microwave source at a frequency of 28 GHz, and study of the synergistic interaction of ECRH with a suprathermal electron distribution, formed by a slow lower hybrid wave at 2.45 GHz; (c) studies of plasmas with high values of poloidal beta using a novel x-ray diagnostic for measuring the current profile.

During the past year significant progress has been made by all three projects and the experimental data collection is nearly complete. Machine operations will cease before the end of the summer. All Ph.D. thesis projects, including thesis defenses, should be completed before the end of this year. Regarding new results in FY1991-92, in area (a) it has been discovered that most of the fast wave power is absorbed on the plasma surface by nonlinear effects (parametric decay instabilities) which then results in strong edge electron heating. The electron energy distribution has been measured by grided probes (energy analyzers) at several locations on the plasma surface. In addition, nonlinear RF power spectra have also been measured at various locations and correlated with the edge electron heating. This explains the failure of previous attempts at high frequency (well above the ion cyclotron frequency) fast wave current drive experiments on other tokamaks. In area (b) the so-called "spectral gap" problem associated with lower hybrid current drive experiments has been clarified for the first time in a quantitative manner. In addition, enhanced fluctuation and transport associated with electron cyclotron wave injection has been noted and quantified. Finally, in project (c) a quantitative study of the electron distribution function, utilizing energetic x-ray spectra, collected by a multiple detector array, has

been completed. At high values of the electron pressure (or beta-poloidal, associated with lower-hybrid driven hot electrons) the importance of the so-called "bootstrap current" (a non-wave driven current, due to toroidal particle orbit effects) has been demonstrated and quantified.

Collaboration with the JET and PBX-M Tokamaks
In collaborative experiments with the Joint European Torus (JET) project the PFC Advanced Tokamak Group has developed a new method to detect the mode structure of plasma instabilities. Previous theoretical work in our group predicted that MHD instabilities generate a characteristic signature of modulated electron cyclotron (EC) microwave radiation. During the past year experiments carried out by PFC personnel at JET have confirmed the existence of the predicted EC fluctuations. These experiments identified coherent modulations in the intensity over a wide frequency band. This data was then analyzed to deduce the spatial resolution of better than 5 cm (5% of the minor radius of the plasma). It appears now that this technique will allow us to probe the internal structure of hot plasma modes with unprecedented spatial resolution.

A related collaborative experiment between the PFC and the Princeton Plasma Physics Laboratory (PPPL) has begun operation this year on the PBX-M tokamak at PPPL. The experiment is designed to test the theoretical prediction that current profile modification can stabilize pressure driven tokamaks and lead to a smaller unit size for fusion power reactors. Modification of the current profile is achieved by means of a lower-hybrid current drive at a frequency of 4.6 GHz and a power level of 1.0 MW. In initial experiments the energetic electron current generated by lower-hybrid current drive was detected by a novel, x-ray imaging camera having a 2.5 msec time resolution. Initial experiments have shown that the RF power generates a current in a localized, off-axis region in agreement with lower-hybrid ray tracing calculations. This experiment will also provide a definitive measurement of the spatial diffusion rate of the energetic electron population. Such energetic electron transport measurements are of fundamental importance in elucidating turbulent transport processes in tokamak plasmas.

X-ray and Nuclear Experiments Group
Three of this year's principal activities comprised, first, the critique of the Brookhaven National Laboratory "cluster-fusion" experiments (see Tech Talk, 13 May, 1992: "*Cluster Fusion Is Illusion, PFC Physicists Find*"); second, the development and initial testing of a deuterium (D)-tritium (T) burn experiment for the Lawrence Livermore National Laboratory (Inertial Confinement Division); and, third, the realization of a PIXE (Particle Induced X-ray Emission) x-ray source for testing, developing, and characterizing x-ray detectors and optics used, for example, by MIT's Center for Space Research. The first two activities are briefly described.

In 1991 the Brookhaven group reported in Physical Review Letters confirmation of their earlier accelerator experiments (in 1989) that utilized clusters of D_20 (100 or so) impacting deuterated targets. In these experiments they claimed to observe fusion rates several orders of magnitude larger than expected on the basis of conventional nuclear physics. Our group directly analyzed the Brookhaven data and found it to be fatally flawed: Of paramount importance, from the line width of 3-MeV protons (from D - D reactions), we established (Phys. Rev. Lett., 30 March, 1992) that a high-energy contaminant of D^+, D^+_2, D^+_3,..., was present along with the clusters, and it was these contaminants — not the clusters — that was responsible for their observed fusion reactions.

One of the crucial issues for inertial confinement fusion is to measure the D - T burn evolution during pellet implosion and burn. The obvious method of attack was to use the 14.1 MeV neutrons from the D - T reactions. However, it can be shown that Doppler broadening of the neutrons is so severe that it obliterates any burn information. It is for this reason that we proposed to develop, in collaboration with our colleagues at LLNL, a D - T burn diagnostic based on the 16 MeV γ-rays that are also emitted from D - T reactions (about 1 in every 10^4 reactions). There is virtually no Doppler broadening to the γ-ray signal, and it therefore accurately mirrors the D - T burn evolution. Using our Cockcroft-Walton accelerator as a source of γ-rays, we have begun to test and develop γ-ray detectors for this program. Eventually this diagnostic will be fielded at Lawrence Livermore National Laboratory.

Fusion Theory, Computations and Thermonuclear Plasmas
In this reporting period our group was impacted by the cancellation of the US Burning Plasma Experiment (BPX) which was conceived as a physics oriented ignition tokamak based on MIT's compact, high magnetic

field, Alcator approach. Our Theory and Computations Group has transferred its recognized leadership capabilities in alpha particle physics to the ITER project which is replacing BPX (on a much more extended time scale). One of the premier open problems concerns the coupling efficiency of the charged particle fusion products to the bulk plasma, needed to maintain the power balance against transport and radiation losses. Our group has strengthened its international leadership in theory and numerical simulation of the Alfvén wave turbulence and orbit stochasticity excited by the fusion born alpha particles (Drs. F. Gang and C. T. Hsu). In the area of tokamak concept improvement (to operate the fusion plasma at elevated plasma pressure for times longer than the magnetic skin diffusion time scale) Dr. J. Ramos has made seminal theoretical and computational contributions in magnetohydrodynamic stability theory. The so-called second stability region which he originally co-discovered with Prof. Coppi has become a major facet of the next large tokamak experiment in the US. A distinguished Russian plasma theorist, L. Zakharov, visiting for two years from Kurchatov Institute, has made a breakthrough in unravelling the rapid collisionless reconnection of the "tearing mode" as the mechanism behind the "internal disruptions" of the plasma current in tokamaks. Dr. Kesner of our group has been part of a theory-experimental team pioneering new operating regimes with plasma current ramp down on the Tokamak Fusion Test Reactor at Princeton University. A doctoral student (R. Betti) of Prof. Freidberg has found two hitherto ignored, but important, effects concerning the toroidal Alfvén eigenmode stability in tokamak plasmas with fusion burn. A high phase velocity "fast Alfvén wave" branch of the tokamak plasma dispersion relation can affect the RF current drive efficiency of an externally applied lower hybrid wave. A. Ram in Prof. Bers' group has developed a theory which explains the observed positive synergism between these two waves.

Small Scale Turbulence and Chaos

An understanding of many coupled nonlinear oscillators is important for models of pattern formation and turbulence in fluids such as plasmas. Experiment and theory in this area are under way. We have recently determined that once sufficient numbers of oscillators are coupled, there are an exponentially growing number of final states and their basins of attraction become fractal. As a consequence, it becomes difficult to specify the final state given small errors in initial conditions. This may explain the great variability observed in natural systems that are effectively systems of coupled oscillators.

Ionospheric Plasma Research Group

Under the sponsorship of NSF and NPRSC, field experiments have been conducted at Arecibo, Puerto Rico using the existing NSF radio facilities (HF heater and incoherent backscatter radars). For the 1992 Campaign conducted by NPRSC, the PFC Ionospheric Plasma Research Group's experiments will be aimed at investigating the anti-Stokes component of the HF-enhanced Langmuir wave turbulence and the generation of ionospheric plasma ducts. New satellite experiments with extensive instrumentation, including ion mass spectrometer, Langmuir probes, retarded potential analyzer, and VLF receivers, have also been planned. These experiments will perform in-situ measurements of nonlinear plasma phenomena such as the excitation of symmetric lower-hybrid sidebands, and formation of electron and ion conics.

Experiments on the laboratory simulation of ionospheric plasma heating with the Versatile Toroidal Facility (VTF) have begun. Our aim is to investigate the effects of significant turbulent scattering and possibly nonlinear mode conversion of the injected electromagnetic waves. This work, jointly supported by the AFOSR and NASA, is aimed at crosschecking the results of the field experiments on the anomalous absorption of electromagnetic waves in the RF-heated ionospheric plasmas. The nature of the toroidal magnetoplasmas in the VTF device is ideal to simulate the geomagnetic flux tube in the space plasma environment. Laboratory experiments have also been planned for the investigation of the diffuse plasma resonances observed in the ionosphere and magnetosphere.

Phase Contrast Imaging Diagnostic

A unique diagnostic to measure long wavelength fluctuations has been developed in the DIII-D tokamak (San Diego) by Professor Porkolab and Mr. S. Coda, a graduate student in the MIT Physics Department. The experimental apparatus was paid for by the DIII-D project, and the personnel time (including the graduate student RA) is paid for by a DOE grant through the Plasma Fusion Center. Density fluctuations at the outer edge of the DIII-D tokamak are being measured under a variety of experimental conditions with the Phase Contrast Interferometer (PCI). This novel diagnostic employs a 7.6 cm wide CO_2 laser beam which is scattered by density fluctuations. The integrated signal is collected by detectors along the line of sight. Cross

correlations between 16 detectors (and therefore as many radial locations) can be carried out and hence wavelengths (correlation lengths) of the order of the CO_2 beam width (7.6 cm) can be measured at frequencies of up to 100 MHz. Present experiments include a quantitative study of low frequency fluctuations (10 kHz - 1 MHz) in the so-called "separatrix" (edge) region of the tokamak plasma. The outcome of these measurements should help to clarify the physics behind the confinement improvement during transition from "low"(L) to "high"(H) confinement regimes. Future upgrades of this experiment will be considered next year. Meanwhile, we are also considering deployment of this diagnostic to Alcator C-MOD, both for measurements of turbulent and quasi-coherent fluctuations, as well as for the detection of launched RF waves.

PLASMA TECHNOLOGY AND SYSTEMS DIVISION

The Plasma Technology and Systems Division, headed by Daniel R. Cohn, develops plasma technology for environmental and industrial applications; develops new diagnostic technology for fusion and low temperature plasmas; investigates advanced materials processing approaches; and performs studies of a variety of aspects of fusion reactor systems. Current research areas include electron beam generated plasmas for treatment of gaseous waste streams (Leslie Bromberg, Daniel R. Cohn, Richard Patrick); DC graphite electrode arc plasmas for treatment of solid waste (Charles H. Titus, Daniel R. Cohn); millimeter wave and infrared diagnostic development (Paul P. Woskov); advanced material processing (Leslie Bromberg, Donna Smatlak); next step experiment and test reactor design (Daniel R. Cohn, Leslie Bromberg); commercial reactor design (Leslie Bromberg, Daniel R. Cohn); and fusion safety and environmental studies (Mujid S. Kazimi). Some highlights are:

Plasma Treatment of Gaseous Waste Streams

An electron beam generated plasma has been built and tested for treatment of waste streams with dilute organic concentrations. The plasma conditions are tuned to optimize process efficiency. Initial tests with CCl_4 concentrations between 20 ppm and 500 ppm in air and water vapor indicate a high level of destruction of the CCl_4 (99.9% destroyed) by electron attachment induced dissociation. The process appears to have the high efficiency consistent with a selective destruction mechanism. Measurements of the reaction products are underway. This work is supported by the U. S. Department of Energy for ultimate use in remediation of CCl_4 contaminated soil. We are working with the Pacific Northwest Laboratories (PNL) in the VOC Arid Site Integrated Demonstration project.

DC Graphite Electrode Arc Plasma Treatment of Solid Waste

In collaboration with Electro-Pyrolysis, Inc. (EPI) and the Pacific Northwest Laboratories, the Plasma Fusion Center is investigating the use of graphite electrode DC plasma arc technology for ultimate use in vitrification of contaminated soil. Vitrification experiments are underway using EPI arc technology. Measurements have been made of efficiency of soil heating and of the quality of the melt product. The Department of Energy has indicated the intent to support these experiments and to also provide funding for a more advanced plasma furnace to be constructed at the Plasma Fusion Center. In addition, EPI and the Plasma Fusion Center are investigating the possible use of graphite electrode plasma arc technology for treatment of ash from hospital incinerators. Experiments are underway on ash from an incinerator at the Massachusetts General Hospital.

Diagnostics Development

Gyrotron scattering systems are being developed for the TFTR and JET tokamaks in collaboration with diagnostics develop groups at Princeton University and at the JET facility in England. The JET experiment will use a 140 GHz gyrotron. A 60 GHz gyrotron will be used on TFTR. In addition, an ultra-wide bandwidth heterodyne measurement device has been used on JET to measure electron cyclotron emission. These measurements of electron cyclotron emission in the millimeter wave range have been used to infer information about ballooning mode phenomena.

New diagnostic techniques for measurement of properties related to waste processing and environmental control are also being conceptually investigated. One approach is the use of laser scattering and laser-produced plasmas to measure the size and composition of particulates.

Next Step Experiment and Test Reactor Design

Design concepts were developed for a Steady Burn Experiment (SBX) device. The objectives of this machine were near-term investigation of steady plasma burn phenomena and nuclear testing with a small, driven

plasma device. An SBX device would complement ITER by accelerating nuclear testing and make it possible to meet the Demonstration Reactor goals that were identified in the National Energy strategy. The SBX device would produce 30 to 50 MW of fusion power, in contrast to the ≥1000 MW power level of ITER. The SBX approach has been incorporated into a new conceptual design study activity which the DOE Office of Fusion Energy is considering for an accelerated nuclear testing mission.

WAVES AND BEAMS DIVISION

The Waves and Beams Division, headed by Richard Temkin, conducts research on novel sources of electromagnetic radiation and on the generation and acceleration of particle beams. Research on novel sources of electromagnetic radiation has concentrated on the use of electron beams to generate microwave and millimeter wave radiation. Of particular interest are the gyrotron, the free electron laser (FEL) and the cyclotron autoresonance maser (CARM). These devices are promising for applications which include plasma heating, industrial heating (for example, ceramics sintering) and high frequency radar. Theoretical research investigates the possibility of extending the range of wavelengths to the infrared, optical and x-ray regions. Research is also conducted on the generation and acceleration of electron beams. A novel, induction linear accelerator is operated at high repetition rates and its beam quality is under investigation. Research is underway on the use of high frequency microwaves to accelerate electron beams with very high gradients, up to 200 MeV/m. The demonstration of such high gradients is critical to the planning of future electron accelerators such as the next linear collider. A strong effort in theoretical studies is conducted on the basic equilibrium and stability properties on non-neutral plasmas and intense charge particle beams. These studies contribute to our understanding of electromagnetic radiation generation and particle beam acceleration.

Gyrotron Research

The gyrotron is a novel source of microwave, millimeter wave and submillimeter wave radiation. It uses a helical electron beam in a high magnetic field to generate radiation by stimulated emission at the electron cyclotron frequency. The gyrotron is currently under development for electron cyclotron resonance heating of the ITER plasma. Gyrotrons are also under development for high frequency radar. These applications require tubes operating at frequencies in the range 100-300 GHz at steady-state power levels approaching 1 MW. The gyrotron research group is led by Ken Kreischer.

Investigation of gyrotron efficiency has concentrated on determining the condition for exciting parasitic modes in gyrotron oscillators and on suppressing their excitation. A gyrotron operating with a tapered cavity in the $TE_{16,2}$ mode at 146 GHz with an 80 kV, 50 A, 3 μs pulsed beam was found to have an efficiency no greater than 22%, about one half the theoretical value. Parasitic modes (or sidebands) at the $TE_{15,2}$ and $TE_{17,2}$ mode frequencies, detuned ±5 GHz from the $TE_{16,2}$ mode, were found to oscillate at low power, less than 1% of the primary mode. These sidebands, although weak, were predicted by theoretical calculations, carried out at the University of Maryland, to cause a significant reduction in device efficiency. A modified cavity was designed to eliminate these parasitic modes. The redesigned cavity achieved 1.3 MW of output power at 146 GHz at 38% efficiency. These results are close to the theoretical efficiency limits predicted by theory and results represent a record gyrotron output power at high frequency. This work will directly impact the CW gyrotron development by Varian.

Gyrotron operation at high frequency has been investigated using magnetic fields of up to 14 T. Frequencies as high as 280 GHz have been achieved in very high order waveguide modes, such as $TE_{42,7}$. Power levels of up to 0.8 MW have been obtained in 80 kV, 50 A, 3 μs pulsed operation. Efficiencies have been relatively low, less than 20%. Research continues on the origin of the low efficiency.

Relativistic Beam Physics Research

The Relativistic Beam Physics Group, led by Bruce Danly, investigates the generation of high voltage electron beams and their application to high power microwave generation. Research programs include investigations of the cyclotron autoresonance maser (CARM), the free electron laser (FEL) and the induction linear accelerator (ILAC).

The CARM is a novel, high power microwave source which is a promising candidate for high power generation at millimeter wavelengths. Recent experiments have demonstrated the first long pulse operation of a CARM oscillator with a Bragg resonator. A Bragg resonator uses a rippled wall to backscatter and confine a

selected mode in a waveguide structure. Output power of close to 2 MW was obtained at an efficiency of about 5% at 28 GHz frequency. The electron beam was a helical beam operating at 450 kV, 80 A in 1 ms pulses. Emission in both the TE_{11} and TM_{01} modes was observed. A CARM amplifier experiment at 17 GHz has been built using the induction linac electron beam. The amplifier will operate in the TE_{11} mode. The electron beam operates at 500 kV, 500 A in 30 ns pulses at repetition rates of up to 1 kHz. Initial results at power levels of up to 1 MW have been obtained.

High Gradient Accelerator Research
The High Gradient Accelerator Experiments Group led by Shien Chi Chen is preparing a novel, 17 GHz microwave driven, photocathode electron injector. This device, sometimes called an RF gun, can generate a 2 ps beam of 2-3 MeV, 50-500 A electrons at high repetition rate. A 5 MW CARM source at 17 GHz will drive the electron gun. This electron beam could be directly applied to microwave generation experiments or it could be used as an injector into a 17 GHz, high gradient accelerator.

The laser driver for the RF gun has been designed. This laser must produce a 0.2 mJ, 1 to 2 ps pulse in the UV, 200-280 nm, to drive the photocathode. A design has been completed of a Ti-sapphire laser system which includes a mode locked oscillator and two stages of direct amplification. This laser eliminates the need for pulse chirping in a fiber and pulse stretching and compression by gratings. The laser system will be built in the next year. The RF gun cavity and the transmission line from the 17 GHz CARM to the RF gun have been constructed and are under test.

Theoretical Research
The Intense Beam Theoretical Research Group led by Jonathan Wurtele has contributed very significantly to our understanding of coherent radiation generation and particle acceleration. Topics covered include coherent radiation sources (CARM, FEL, gyrotron, relativistic klystron, relativistic magnetron), beam-beam interactions, cyclotron resonance accelerators, two-beam accelerators, photocathode design, and other topics. Multimode codes have successfully predicted new phenomena in both the cyclotron autoresonance maser and free electron laser amplifier.

RELATIVISTIC ELECTRONICS DIVISION

During the past year we have continued research activities in the generation of coherent electromagnetic radiation using relativistic electron beams as the lasing medium. Most of our research has been concentrated on the free electron laser and the relativistic klystron.

We have discovered a novel free electron laser (patent applied for) in which the axial guide magnetic field was arranged so as to oppose the magnetic wiggler field. This geometry differs from the conventional one in which the two fields reinforce each other. The "Reversed Field FEL" has yielded unprecedented large powers in the millimeter wave regime. More specifically, we have obtained 60 MW of output power with an efficiency of 27%. This discovery caused considerable excitement in the free electron laser community.

In addition to the above mentioned success, the Reversed Field Free Electron Laser also yielded a quite unexpected physics phenomenon which now goes under the name of "antiresonance". This anti-resonance has now been interpreted as being due to the motion of off-axis electrons.

A precise measurement of the frequency of our free electron laser amplifier exhibits a slight frequency upshift from the input driver frequency. This novel phenomenon is being investigated by our theoretical group. The reason for the upshift appears to be caused by rapid temporal changes of the effective refractive index of the pulsed electron beam.

K-12 EDUCATIONAL OUTREACH ACTIVITIES

Our K-12 educational outreach efforts have continued, and last year we again reached over one thousand students and teachers. The PFC hosted two open houses, one each for high school and middle school students and teachers, special visits and tours by classes from over fifty schools, and visits by faculty, graduate students and staff to several schools. The goals of these outreach efforts are twofold. The first is to convey to students a basic understanding of what plasmas are, how they behave, and the role they play in the production of fusion energy. Our secondary goal is to interest students in the fields of science and engineering, and to give them a

sense of the excitement and the rewards that come with scientific discovery and experimentation. PFC graduate student Tom Hsu represents the Plasma Fusion Center as a member of the MIT Council on Primary and Secondary Education. He has also formed the Cambridge Physics Outlet with a group of PFC graduate students- Adam Brailove, Darren Garnier, Chris Kurz and John Urbahn. This group is developing a new and innovative high school science curriculum which has been successfully tested at an independent high school in Weston, MA and which has received considerable attention from the local media in the past year. They have designed and built 12 simple apparatuses with accompanying lesson plans that can be used to demonstrate about 40 physics experiments. The group's philosophy of cost-effective, hands-on learning was presented at the National Science Teachers Association convention in March of this year, and they are now in the process of collaborating with the Boston Museum of Science to incorporate some of their hands-on material into exhibits for teaching and for teacher workshops there. This year, the group has also begun working with middle school teachers to develop a science curriculum for grades 5-8.

AFFIRMATIVE ACTION

The Plasma Fusion Center is committed to increasing the number of women and minorities at those levels of the work force where there is significant underrepresentation. Our success in meeting this objective is dependent on the pool of applicants available at each level. For example, 81% of both the SRS-administrative and support staff are women, while 17.9% of both support and service staff are considered Black minorities. In these categories, we have found that our search procedures, which utilize both internal and external resources, have turned up an excellent supply of highly qualified candidates. On the other hand, at the SRS- technical level, our success is more modest: approximately 4.3% of SRS- technical staff are women, while 10.8% are minorities, slightly more than half of whom are considered Asian minorities. These numbers reflect the applicant pool which, for the 6 month period October, 1991 though March, 1992, was 4.9% women and 6.7% identified as minorities, primarily Asian American. We are attempting to enlarge the reservoir of qualified underrepresented applicants in the near term by more intensive dissemination of job postings to organizations specifically concerned with opportunities for women and minorities and, in the long term, with a substantial K-12 and undergraduate outreach effort which encourages women and minorities to pursue careers as scientists and engineers.

APPOINTMENTS AND PROMOTIONS

Appointments include: Mr. Henry Bergler (Twixtel Technologies), appointed Network Manager in the Toroidal Confinement Division; Mr. Eammon Byrne (Sullivan and Cogliano), appointed Control and Power Systems Engineer in the Toroidal Confinement Division; Dr. Rejean Boivin (Princeton University), appointed Experimental Research Scientist-Temporary in the Toroidal Confinement Division; Mr. Richard Camille (MCE Systems), appointed Mechanical Engineer in the Fusion Technology and Engineering Division; Mr. Edward Fitzgerald (Massachusetts Institute of Technology), appointed Technical Sponsored Research Staff in the Toroidal Confinement Division; Dr. Amanda Hubbard (Hydro Quebec-IREQ), appointed Experimental Research Scientist in the Toroidal Confinement Division; Dr. Stephen Jones (Cornell University), appointed Postdoctoral Sponsored Research Staff in the Physics Research Division; Dr. Chungpin Liao (Massachusetts Institute of Technology), appointed Postdoctoral Sponsored Research Staff in the Plasma Technology and Systems Division; Dr. Franco Paoletti (CNR at JET), appointed Postdoctoral Sponsored Research Staff in the Physics Research Division; Dr. Jaroslaw Pisera (Northeastern University), appointed Mechanical Engineer in the Fusion Technology and Engineering Division; Dr. Alexei Radovinski (Moscow Institute for Instrument Building), appointed Research Engineer in the Fusion Technology and Engineering Division; Mr. Christopher Reddy (Cordell Engineering), appointed Mechanical Engineer in the Toroidal Confinement Division; Dr. Pei-Wen Wang (Massachusetts Institute of Technology), appointed Postdoctoral Sponsored Research Staff in the Fusion Technology and Engineering Division; and Dr. Kevin Wenzel (Oak Ridge Associated Universities), appointed Experimental Research Scientist in the Physics Research Division.

During the past year, Institute research promotions in the Plasma Fusion Center include: Dr. Bruce Danly, promoted to Principal Research Scientist in the Waves and Beams Division; Dr. Jesus Ramos, promoted to Principal Research Scientist in the Physics Research Division; and Dr. Yuichi Takase, promoted to Principal Research Scientist in the Toroidal Confinement Division.

Internal promotions within the Plasma Fusion Center have included: Dr. Paul Bonoli, promoted to Leader of the RF Interactions and Modelling Group in the Physics Research Division; Mr. William Byford, promoted to

Project Engineer, Office of Technical Operations and Planning, and Assistant Safety Officer, Office of Environment, Safety and Health; Dr. Emmanouil Chaniotakis, promoted to Experimental/Theoretical Research Scientist in the Plasma Technology and Systems Division; Dr. Shien-Chi Chen, promoted to Leader of the High Gradient Accelerator Experiments Group in the Waves and Beams Division and Leader of the Microwiggler Research Group in the Relativistic Electronics Division; Dr. Bruce Danly, promoted to Leader of the Relativistic Beam Physics Group in the Waves and Beams Division; Mr. Stephen Fairfax, promoted to Leader of the Operations Section in the Toroidal Confinement Division; Dr. Catherine Fiore, promoted to Head of the new Office of Environment, Safety and Health; Dr. Fongyan Gang, promoted to Theoretical Research Scientist in the Physics Research Division; Dr. John Goetz, promoted to Experimental Research Scientist in the Toroidal Confinement Division; Dr. Robert Granetz, promoted to Leader of the MHD Research Group in the Toroidal Confinement Division; Mr. David Gwinn, promoted to Head of the new Office of Technical Operations and Planning; Dr. James Irby, promoted to Leader of the Diagnostic Coordination Group of the Experiments Section in the Toroidal Confinement Division; Dr. Kenneth Kreischer, promoted to Leader of the Gyrotron Research Group in the Waves and Beams Division; Dr. Paul Linsay, promoted to Leader of the Small Scale Turbulence and Chaos Group in the Physics Research Division; Dr. John Machuzak, promoted to Experimental Research Scientist in the Plasma Technology and Systems Division; Dr. Joseph Minervini, promoted to Associate Head of the Fusion Technology and Engineering Division; Dr. Robert Pillsbury, promoted to Leader, Electromagnets and Structural Group in the Fusion Technology and Engineering Division; Mr. Bradford Smith, promoted to Leader, GEM Magnet Development Group in the Fusion Technology and Engineering Division; Dr. Richard Thome, promoted to Head of the Fusion Technology and Engineering Division; and Prof. Jonathan Wurtele, promoted to Leader of the Intense Beam Theoretical Research Group in the Waves and Beams Division and Leader of the Accelerator Theory Group in the Relativistic Electronics Division.

GRADUATE DEGREES

During the past year, the following students graduated with theses in plasma fusion and related areas: Vincent Adzovie, M.S. in Mechanical Engineering; Joseph Armstrong, M.S. in Mechanical Engineering; Riccardo Betti, Ph.D. in Nuclear Engineering; Robert Bieri, Ph.D. in Nuclear Engineering; Dwight Caldwell, M.S. in Aeronautics and Astronautics; Carson Chow, Ph.D. in Physics; Tak-Sum Chu, M.S. in Nuclear Engineering; Keith Groves, Ph.D. in Earth, Atmospheric and Planetary Sciences; Robert Duraski, M.S. in Nuclear Engineering; Haisam Haidar, M.S. in Mechanical Engineering; David Hale, M.S. in Mechanical Engineering; Sangkwon Jeong, Ph.D. in Mechanical Engineering; Peter Legorburu (Paparavitas), M.S. in Physics; Chungpin Liao, Ph.D. in Nuclear Engineering; James Ludlam, M.S in Mechanical Engineering; Onozuka Masanori, M.S. in Nuclear Engineering; Philip Michael, Ph.D. in Mechanical Engineering; Daniel O'Lone, M.S. in Ocean Engineering; Scott Peng, Ph.D. in Nuclear Engineering; Shuanghe Shi, M.S. in Nuclear Engineering; Kenneth Vilece, M. S. in Nuclear Engineering; and Pei-Wen Wang, Ph.D. in Nuclear Engineering.

RONALD R. PARKER
DIRECTOR
MIT 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 MIT 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, RLE's research interests have branched out in many directions, and in fact, several of these interests have precipitated the formation of additional laboratories. Research within RLE is conducted by approximately 55 faculty members who are 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 200 graduate students and 75 undergraduates have worked on research projects within RLE. Major support 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 is composed of two major thrusts and seven smaller focus areas. One major thrust is centered on electronics and optics, and the other is centered on language, speech, and hearing. Each of the seven smaller focus areas often has substantial overlap with other research in RLE.

In the following remarks, several research highlights from 1991 are briefly mentioned. The interested reader can obtain further information from ***RLE Progress Report No. 134***, which describes research activities during calendar year 1991.

ELECTRONICS AND OPTICS

Quantum-Effect Devices

Increased emphasis was placed on the design and characterization of electronic devices whose behavior is critically dependent on quantum effects. One of the most remarkable inventions has been the single-electron transistor, which turns on and off as each new electron is added to the device's gate terminal. Considerable theoretical modeling for these devices was completed by Professor Patrick Lee. Professor Marc Kastner continues to evolve the design of the transistor so that it can operate at higher temperatures.

Optics and Devices

There has been much interest in repeaterless, transatlantic optical fiber transmission, but to date, it has not been possible to use solitons (pulses whose shape does not change over time or distance) in these systems. Professor Hermann Haus has demonstrated how to avoid these fundamental difficulties so that solitons can be introduced to permit wavelength division multiplexing for future systems that will be installed later this decade.

Surfaces and Interfaces

In theoretical condensed matter physics, Professor John Joannopoulos has had great success in modeling a variety of surface transformations based only on fundamental physical constants. These results have been transformed through visualization techniques to provide vastly improved insights into the nature of surface restructuring and other transformations. The introduction of visualization technology is providing a "theoretical microscope," which allows for the inspection of condensed matter systems in ways that are not possible with conventional physical microscopes.

Circuits and Systems

There has been much new and interesting research into timing optimization and verification led by Professor Srinivas Devadas. In the past, it was often thought that the introduction of redundancy into digital systems was necessary in order to improve speed. It has now been shown that circuits can be produced which are both prime irredundant and just as fast as the previously redundant circuits. This result is important because these irredundant circuits are easily testable and can benefit from other techniques introduced by Professor Devadas for the synthesis of digital logic circuits which are guaranteed to be completely testable.

LANGUAGE, SPEECH, AND HEARING

Speech Communication

Speech communication research, under the direction of Professor Kenneth Stevens, has sought to understand the fundamental nature of speech production and perception. Results obtained by Research Scientist Dr. Stefanie Shattuck-Hufnagel have examined the role of pitch accent placement in auditory perception, particularly when these emphases help the listener to disambiguate ambiguous utterances. These new comprehensive studies have particular significance not only for the understanding of human perception, but also for insights that stimulate new techniques for speech recognition which utilize the pitch contour of an utterance in a way that substantially improves the accuracy of recognition.

Auditory Physiology

Professor Nelson Kiang has obtained a new $4.5 million grant from the National Institutes of Health to establish a speech and hearing graduate program through the MIT Whitaker College of Health Sciences and Technology. This achievement is significant because it will lead to a new degree program in speech and hearing that will be aimed at twenty students annually. RLE faculty and others will be major contributors to this new program.

FOCUS AREAS

Manufacturing Processes

Under the direction of Professor David Staelin, Dr. Ashraf Alkhairy completed his doctoral thesis on new methods of experiment design to improve products and manufacturing processes. These techniques have already been applied in industry, where reductions in the number of required experiments by factors of more than four were demonstrated in order to obtain the needed parameters for optimal manufacturing. These new techniques for experimental design in a manufacturing context are exceedingly useful and can also be used in a variety of scientific problems.

Digital Signal Processing

Professor Gregory Wornell has introduced new techniques for the fractal modeling of signals. Many natural processes can be represented in this way, and the resulting signals are well suited for use in noisy channels of simultaneously uncertain duration and bandwidth. Such chaotic signals are also well suited for broadband communication applications, and are of particular interest to new RLE initiatives in personal, wireless communication networks.

Advanced Television and Signal Processing

RLE's Advanced Television and Signal Processing Group is the only university program that is directly represented in the competition conducted by the Federal Communication Commission (FCC) to establish a United States standard for high-definition television. The RLE system will be evaluated during the summer of 1992, and demonstrations have already indicated the very high quality of audio and video provided by this system.

Electromagnetics

A wide variety of electromagnetic techniques are being investigated by Professor Jin Au Kong and Research Scientist Dr. Sami Ali to characterize superconducting phenomena. These techniques include interconnect structures, waveguides, and antennas that are being realized in superconducting materials. These activities are part of a broad MIT consortium in superconductivity that involves MIT Lincoln Laboratory, AT&T Bell Laboratories, IBM, and other MIT on-campus research programs.

Optical Communications

Another consortium has recently been funded to study wideband, all-optical networks. It will support the research of Professors Hermann Haus, Erich Ippen, and Jeffrey Shapiro. Other on-campus MIT research programs, MIT Lincoln Laboratory, AT&T Bell Laboratories, and Digital Equipment Corporation are contributing to this new consortium.

JONATHAN ALLEN

Sea Grant College Program

The Sea Grant College Program, which is modeled after the Land Grant Program, includes funds for research, education, and technology transfer directed toward wise utilization of marine resources. MIT received one of the first grants in 1969 and has been a leading participant in the national program ever since. By 1976 MIT's Sea Grant contribution was so significant that the Institute was designated a Sea Grant College Program, the only private university to receive this recognition. Sea Grant College status provides greater funding and also confers a responsibility to work with marine researchers throughout the Commonwealth.

Funds are distributed among the 29 Sea Grant Programs in a competing grant process from the National Oceanic and Atmospheric Administration through its National Office of Sea Grant. Each program is required to match each dollar of its federal grant with $0.50 from non-federal sources—including industry, state and local governments, universities, and private foundations. Congress established this matching provision to ensure that Sea Grant universities would be responsive to public and industry needs, and to encourage cooperation between those who do the research and those who use it. Sea Grant provides funds explicitly for technology transfer through its mandate for advisory services and education as well as research.

In FY 1992 the National Office of Sea Grant awarded MIT $1.67 million; essentially the same as FY 1991. MIT, industry partners, the Commonwealth, the Massachusetts Water Resources Authority (MWRA), and the US Olympic Committee provided nearly $1.4 million in matching funds. In addition, MIT Sea Grant also received more than $1.2 million in related research from other federal agencies. In all, these funds provided partial support for about 14 faculty members, 14 post-doctoral fellows and 41 students from seven departments including Civil, Chemical, Ocean and Mechanical Engineering; (and partial support for faculty at UMASS/Boston, UMASS/Amherst, Boston University, and Northeastern University.)

RESEARCH

The direction of Sea Grant research at MIT is guided by both the unique resources of the Institute and the needs of the marine community. This research is currently focused in five theme areas: autonomous mobile instrumentation platforms, marine biotechnology, ocean and coastal processes, ocean engineering, and technology development and management for ocean uses. Investigators from other Massachusetts universities participate in some of these research areas. Each area is discussed below.

In addition to the five theme areas, Automation in the Manufacture of Marine Systems continued as one of Sea Grant's strongest activities, although it is now supported entirely from sources outside Sea Grant. Research has focused on applying new methods of representing shape in an efficient manner, on transferring geometric data between design and manufacturing systems, and on extending the theoretical understanding and numerical techniques for describing propellers.

The overall objective of Sea Grant's research in *Marine Biotechnology* is the advancement of technology that can contribute effectively to better use of the biological resources of ocean and coastal ecosystems. Recent and ongoing research has focused on the application of biotechnology to reproductive barriers in aquaculture-raised fish, the improvement of technology for seafood processing, and biochemical markers for pollution damage in fisheries.

Interdisciplinary Sea Grant investigations of *Ocean and Coastal Processes* seek to describe and model currents in order to estimate the fate of sediments and chemical compounds in near-shore environments. 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 identify microorganisms in aquatic ecosystems and a way to extract toxic compounds from water.

Through Sea Grant's advisory activities, undergraduate students have been working on a variety of coastal problems, such dealing with noxious algae that have recently spread from Swampscott to Lynn and Revere; monitoring the PCB cleanup in New Bedford Harbor; and deciding where to place dredge spoils from proposed dredging of Boston Harbor ship channels. Dr. Eric Adams of Civil Engineering oversees *Ocean and Coastal Processes*. Additional research on Massachusetts Bay and Boston Harbor is carried out under Sea Grant's first Marine Center project (see below).

Sea Grant research under its *Ocean Engineering* theme includes research on understanding slow-drift oscillations of floating bodies, such as offshore-platforms, as a result of non-linear wave affects. This research is very important in assuring the safety of offshore structures. Other research involves developing technology for the difficult task of analyzing marine pollutants *in situ*. In addition, a project in *Ocean Engineering* compliments Sea Grant's Autonomous Underwater Vehicles research carried out under the Marine Center (see below). Through a novel analysis of how fish swim, Sea Grant-supported researchers may learn how to design more efficient propulsors for future unmanned underwater vehicles.

In Sea Grant's *Technology Development and Management* theme area, the program investigates new programs that may develop into future theme areas or that may show particular promise in solving important marine related problems. Theme areas in Automation and in Autonomous Mobile Instrumentation Platforms began as projects in *Technology Development.*

In order to more fully exploit opportunities for cooperative, multi-sponsor programs with industry, Sea Grant established the Marine Center project under its *Technology Development* theme area. Sea Grant funds are used for initiating research projects and matching industry and government funds are obtained to expand research opportunities. Initially, Sea Grant focused on using joint research activities as a powerful technology transfer mechanism. The projects undertaken were extensions of research projects that had been carried out under Sea Grant funding for several years. These projects represented a bridge between Sea Grant's Collegium program and its basic research program, closely tying together research and advisory efforts.

Because Sea Grant needs more "leverage" from its funds, the program decided to undertake a few major multi-year, multi-sponsor research projects under the Marine Center concept. Such a concept was tested in developing the automation theme area in which Sea Grant funds were used to establish a small group of researchers with expertise and interest in the area. With modest Sea Grant matching funds the researchers obtained long-term funding from industry and other government agencies.

Sea Grant established a multi-sponsor Marine Center research project focusing on pollution in Boston Harbor and Massachusetts Bay as its first Marine Center project. Sea Grant already has strong collateral support from the National Science Foundation (NSF), the Environmental Protection Agency, and the MWRA. This project adds to and compliments Sea Grant's coastal processes research and involves researchers at UMASS/Boston as well as those from MIT.

The second major project carried out under the Marine Center involves underwater systems. Titled "Autonomous Underwater Vehicles," the project encompasses a broad program aimed at making autonomous underwater systems useful tools for coastal and oceanic research and/or monitoring programs. The investigations focus on intelligent control, navigation, and applications of autonomous vehicles to specific scientific missions. The project is sponsored by Sea Grant, Charles Stark Draper Laboratories, Lockheed Corp., International Submarine Engineering Ltd., Office of Naval Research, NSF, and Naval Undersea Research Program.

Other work on underwater systems is carried out under Sea Grant's research theme area *Autonomous Mobile Instrumentation Platforms.* Developments in underwater vehicle research can be tested 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 interactive computer-based information/education program about underwater vehicles (see below). The park attracts about one million visitors annually. Professor Henrik Schmidt of the Department of Ocean Engineering oversees this research area as associate director for research and James G. Bellingham directs the AUV Lab.

MIT Sea Grant successfully bid on two other research projects administered by the Office of Sea Grant. Fisheries Engineer Clifford Goudey was awarded additional support to continue his work in mitigation of noxious algae fouling Revere-area beaches. And Professor Ralph Mitchell, of Harvard University, was awarded support to study zebra mussels, an exotic invading species threatening inland water supplies and ecosystems.

EDUCATION

The educational goals of Sea Grant are to provide learning opportunities to university students, professionals, and the public. Support for graduate students is included in almost every research project. In addition, the program continues to provide major support for marine-related Undergraduate Research Opportunities Program (UROP) projects.

As a result of his work integrating undergraduates into real-world, multidisciplinary, research and development projects, Professor Chryssostomos Chryssostomidis, was awarded the MIT Professorship in Teaching Innovation. This education effort is also supported by NSF and the Office of Sea Grant.

Sea Grant UROP directly provides $25,000, and support from other departments (primarily Ocean Engineering) and from Draper Laboratories raises the total funding to $45,000. About 15 UROPs are supported during the spring and fall terms and 10 students are supported for a full summer. Undergraduates from Aeronautics and Astronautics, Civil, Ocean, Mechanical, and Electrical Engineering and Computer Science were represented, as well as students from Physics and Earth, Atmospheric, and Planetary sciences.

The Dean A. Horn Award was established in 1982 to honor the contributions of a former Sea Grant director. The award is given to the marine-related UROP project that best reflects Mr. Horn's high regard for significant innovative marine research projects carried out with competence and reported with clarity. In September 1991, the award was given to Jennifer Caulfield, a senior in Course I for her research in modeling the uptake and fate of PCBs by marine mussels.

A computer display now in Charlestown was field tested at the New England Aquarium with such success (and reliability) that the Aquarium is now seeking funds to obtain an identical configuration for a permanent educational display. Work has begun on a display for the Aquarium that will use animation, sound and text in an interactive computer-based exhibit to explain the sewage system, the changes it is going through, and the Boston Harbor cleanup. In addition, a computer program covering the same material, but in greater depth, was developed for middle-school students to use in class. This program was incorporated into the MIT Summer Teacher's Institute.

The 1991 Sea Grant Lecture was a symposium on the Scientific Visualization of Physical Phenomena. The proceedings of this symposium were edited by Nicholas M. Patrikalakis, professor in the Department of Ocean Engineering, and published by Springer-Verlag.

MIT Sea Grant had its fourth nominee accepted as a John A. Knauss Sea Grant Policy Fellow. Graduate student Diedre Kimball, of the UMASS/Boston Environmental Sciences Program, is participating actively in the office of Congressman Gerry Studds.

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 E. Eric Adams, senior scientist in the Department of Civil Engineering. Norman Doelling, assistant director, oversees the operation of Sea Grant Advisory Services and Education.

MIT Sea Grant administers the Doherty Professorship, endowed by the Henry L. and Grace Doherty Foundation in 1973, for junior faculty at the Institute. Continuing to hold the appointment are Professor Harri Kytomaa of the Department of Mechanical Engineering, who is continuing research in on resuspension and settling of particulate beds, and Professor Linda Cima of the Department of Chemical Engineering, who is continuing research on medical applications for marine biopolymers. In the spring of 1992, Professor J. Robert Fricke, assistant professor of Ocean Engineering, was awarded the two-year chair for his proposal to develop instrumentation for under-ice exploration with an autonomous underwater vehicle.

We are pleased that the Doherty Foundation has agreed to fund a full professorship in Ocean Engineering.

TECHNOLOGY TRANSFER

Sea Grant's legislation explicitly provides funds for technology transfer as an integral part of the program. Additionally, the technology transfer projects are designed to bring current user needs to the attention of MIT Sea Grant researchers. Thus, technology exchange may be a better description of our efforts.

The *MIT Sea Grant Marine Industry Collegium* promotes the active transfer of marine research and technology through the sponsorship of workshops, distribution of publications and research reports, and direct interaction with members. Since 1975, the Collegium has provided member organizations with the opportunity to attend several technical workshops and symposiums per year. Recently, the Collegium program has collaborated with Draper Laboratories and other campus organizations in the sponsorship of symposiums. During the past year, Collegium workshops have included applications of advanced composites for offshore structures; scientific and environmental data collection with autonomous underwater vehicles; and interaction of flow fields with cables, flexible risers, and tethers.

MIT Sea Grant's *Center for Fisheries Engineering* is recognized as an important national resource for technical studies of fishing gear and vessel design. Using tow tanks at MIT and at the David Taylor Research Center, in Bethesda, Md., the Sea Grant Center tests scale-model trawl systems and conducts courses for fishermen. Industry turns to the Center for testing and evaluation of new trawl net designs and, recently, innovative aquaculture pen systems. The Center also assists the local fishing industry with solutions to technological problems on gear design, selectivity, and marine mammal interactions. In addition, fisheries engineer Clifford Goudey has been instrumental in testing technology to clean up noxious algae contaminating Revere beaches.

The *Massachusetts Marine Liaison Service (MMLS)* works with state and federal agencies and the public, to identify and address local and regional needs in fisheries and coastal zone management. For example, marine advisory agent Madeleine

Hall-Arber is working with the Metropolitan District Commission to educate boaters and industrial fresh-water users to minimize the impact of zebra mussels. MMLS is also working with the New England Fishery Management Council to provide a social and economic impact assessment of new fisheries regulations. Hall-Arber currently serves on the advisory board to the Massachusetts Coastal Zone Management Program, the New England Marine Advisory Council and the Women's Fisheries Network. Public education efforts continue through exhibits, participation in conferences and festivals, and articles in *Commercial Fisheries News*.

The MIT Sea Grant *Communications/Information Service* produced a variety of publications in 1991-1992, including technical reports, directories, and a quarterly newsletter. The service also continued its involvement in *Nor'easter*, a magazine (circ. 12,000) that informs readers about Sea Grant's research in all of New England. Notable publications produced by the service included a guide to water pollution and water quality problems for municipal officials, written by Hall-Arber. In addition, the service wrote and produced the interactive computer programs referred to above, and wrote and assembled exhibit on underwater exploration for the Hart Nautical Gallery. Working with the press resulted in stories in *Popular Science, Technology Review, The Boston Globe*, and other newspapers, as well as national and international trade journals and radio programs. In addition, both Cable News Network (CNN) and the New Film Co. produced video features on MIT Sea Grants autonomous underwater vehicle research. The CNN video was broadcast to a national audience; the New Film video was used to teach middle-school students throughout Massachusetts about engineering research.

During the year, MIT Sea Grant continued to develop support for faculty and graduate students in public service through application of new technology to marine and coastal problems in Massachusetts. Projects involved helping solve problems with noxious algae in Revere, tracing pollutants in mussels, studying marine dredging policy and regulation, and compiling a directory of marine-monitoring programs in Massachusetts. This project provides additional support for MIT faculty and for its graduate students.

CHRYSSOSTOMOS CHRYSSOSTOMIDIS

Technology and Development Program

INTRODUCTION

The Technology and Development Program's (TDP) primary mission 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. Its specific objectives are to:

- Promote an awareness of the relationship between science, technology, and development on the part of faculty and students at MIT;
- Provide a focal point for the activities of faculty, students, and visiting scholars interested in the field of technology and development;
- Assist the faculty, students, and staff of collaborating institutions in other countries to develop research and academic interests consistent with their national needs;
- Serve as a contact for interested organizations outside MIT (government, academic, private sector) to access the Institute's resources and its knowledge of developing countries -- particularly of their socio-economic and technological problems.

The TDP carries out these objectives through research, academic programs, and contacts with international and national organizations that have an interest in broad areas of technology and development. These programs are conducted solely on the basis of strong MIT faculty support and willingness to participate. In order to fully utilize available resources, the TDP is structure to interact with other academic departments and research centers throughout MIT.

CURRENT RESEARCH PROGRAMS

In October 1990, TDP finalized a Collaborative Program on Science, Technology, and Development between MIT and the American University of Beirut. The purpose of the program is to focus on specific joint research projects which are relevant to the reconstruction and redevelopment of both physical and institutional resources in Lebanon. Now in its second year, the program has completed one project in Wastewater Treatment (Civil Engineering) and is actively conducting five additional projects in: Power Systems Reconstruction (Electrical Engineering and Computer Science); Residential Structure Rebuilding (Urban Studies and Planning); Passenger Transportation Options (Center for Transportation Studies); Solid Waste Disposal (Mechanical Engineering); and Educational Technology (Center for Educational Computing Initiatives). Program participation has included 12 faculty/research staff and 8 graduate students from MIT; and 8 visiting faculty and 9 visiting scholar graduate students from AUB. Four additional AUB faculty members have visited MIT on three month faculty development scholarships.

CURRENT EDUCATION INITIATIVES

The TDP-sponsored Middle East Program at MIT completed its sixth year with 10-12 graduate students participating each semester. The program enables students with an interest in the Middle East to develop an expertise in the area in addition to their own academic fields of specialization. The program examines the processes of socio-economic change, technological development, political change, institutional development, capital flows, and business and investment patterns in the region. Three interdepartmental courses are offered by the program: Politics, Growth, and Development in the MIddle East; Technology, Business and Public Policy in the Middle East; and Reconstruction. The Middle East Program is under the direction of Professor Nazli Choucri, TDP Associate Director, and involves faculty from the Department of Political Science, Department of Economics, the History Faculty, the Department of Urban Studies and Planning, the Sloan School of Management, the Department of Civil Engineering, the Science, Technology and Society Program, and the Aga Khan Program in Islamic Architecture.

ORGANIZATION

The TDP Director is Professor Fred Moavenzadeh, George Macomber Professor of Construction Management in the Department of Civil Engineering. Professor Nazli Choucri of the Department of Political Science is the Program's Associate Director and Chairman of the Policy Committee. Other Committee Members are Professors Moavenzadeh, and Jack R. Ruina of the Department of Electrical Engineering.

FRED MOAVENZADEH

LIBRARIES

The dedication of the new Rotch Library of Architecture and Planning on December 5, 1991 represented the culmination of almost two decades of hoping and planning. The facility with its expanded reading and collection space has already garnered architectural and building awards. The library has attracted great interest among librarians and architects throughout the world as well as being received with great appreciation by members of the MIT community.

Of comparable moment during the past year was the unveiling of the Libraries' new CD-ROM based catalogue -- CD-Barton. The use of CD-ROM as the principal source for a public access library catalogue is unique to MIT among academic libraries. The new system offers the advantage of expanded search capability as well as reducing response time and queuing problems. In addition, the implementation of CD-Barton will enable the Libraries to mount an online acquisitions system on the Geac mainframe.

The Libraries and Information Systems (IS) continued to work closely on a number of information-based efforts. The umbrella for this is the "Distributed Library Initiative" (DLI), a multi-year project to expand the scope and depth of information services on the MIT campus. The DLI was the subject of a day long meeting in January attended by MIT faculty, research staff, Information Systems personnel, and staff from the MIT Libraries. Among the projects encompassed under the DLI umbrella are a new library operations system that will replace the Geac system; the mounting of MEDLINE (National Library of Medicine database) and other databases on the campus network; an online reference service -- Online With Libraries (OWL) -- based on the Athena online consultant model; upgrading the search engine that supports the online catalogue on the campus network; the possibility of having multiple access to CD-ROM databases via the network; and two large-scale, multi-university programs: The University Licensing Program (TULIP) and the DARPA computer science technical reports project. In TULIP, MIT will participate with seven other universities and consortia in mounting on campus networks the full text of a number of journals in the field of materials science and engineering published by the Elsevier Publishing Company. The DARPA project, to be funded by the Defense Advanced Projects Research Agency, is a joint effort among Carnegie-Mellon University, Cornell University, MIT, Stanford University, and the University of California, Berkeley, to place online the full text of computer science technical reports. The Laboratory for Computer Science is the principal investigator, with the Libraries providing data and scanning services to build this technical reports database. Finally, the Libraries and IS have been working with the MIT Press to experiment with placing the full text of Press journals online on the network. The Libraries and Information Systems are collaborating at many organizational levels to implement projects that held to realize the goals of the DLI.

The Library Council composed of the director, associate directors, and department heads founded a new program entitled "Library Council Special Achievement Awards." The purpose of the awards are to recognize work units that fulfilled one or several of three criteria: (1) implemented new procedures or changed existing procedures in a way that significantly improved service; (2) realized a significant increase in productivity or a significant cost savings by streamlining procedures or re-designing workflow or work assignments; (3) experimented with new services or processes which demonstrate creative approaches. The awards for 1991/92 were given to the Psych Liaison Program

(library instruction and bibliographic assistance for a large undergraduate course); the Monograph Copy-Based Cataloguing Section of Bibliographic Access Services for several streamlining initiatives which resulted in increased productivity; and an informal staff group named The Navigators who developed expertise in working with the campus network and then extended that knowledge to the wider staff. Other units cited for their efforts during the year were the Systems Office, the Barton Operations Group, the Reference and Information Services Committee, and the Space Planning Group for the technical services area in Hayden Library.

The Libraries continued to support a number of programs during IAP. In January 1992 they covered a wide range of topics including career information, CD-ROM technology, preservation microfilming, patents, sports information, thesis preparation, bookbinding, MIT technical report collections, and access to machine readable datafiles.

An Advisory Committee on Sexual Harassment was appointed in February, 1992. It was charged by the Director of Libraries to monitor developments in the area of sexual harassment awareness and education at the Institute and beyond; to serve, individually, as resource persons for members of the Libraries' staff seeking information or advice; and to develop a "road map" document specifically for the Libraries along the lines of the MIT publication issued in 1991. By year end the Committee had completed a draft of the "road map" and had also identified as a major issue for future discussion the problem of harassment of staff by the public.

The Libraries' budget continued to be buffeted by a variety of factors including the economy in general, increased prices for scholarly journals, Institute-based constraints, and an ever-growing need to support new and developing collections and services. The prospect of another round of serial cancellations looms for the coming year given the portent of further decline in the value of the dollar against major European currencies and what appears to be another round of double-digit price increases projected by a major publisher of scientific journals. The Libraries were a major focus of the study of indirect costs undertaken at MIT during the year. The possibility of changes in the allocation of library costs to research poses yet another threat to fiscal stability.

The MIT Libraries hosted the 14th biennial meeting of the International Association of Technological University Libraries in July of 1991. Over 100 participants from North America, Europe, Asia, Latin America, and Australia spent a week hearing presentations and engaging in formal and informal discussions on the issue of the impact of technology on library information services. The MIT Libraries also sponsored a session of the Communications Forum in December, 1991, on the subject of scholarly communication. Outside speakers represented the fields of research libraries, learned societies, and commercial publishers and looked at the intellectual, economic, social, and legal aspects of scholarly publishing in the electronic age.

Institute Archives

The staff devoted considerable effort to the implementation of the new bibliographic control system for archival records. MIT is using the Archives and Manuscripts program on the Research Libraries Information Network (RLIN) to create machine-readable records for both manuscript and archival collections. The first records were entered in May 1992 and will subsequently appear in both the national RLIN database and local MIT online catalogues. The Archives, in cooperation with the Registrar's Office and the Microreproduction Laboratory,

embarked on a major project to preserve MIT's permanent student records. During the year, student transcripts from 1949 to 1965 were transferred to the Archives and microfilming was begun. When completed both the paper records and a security microfilm copy will be stored off-site. Archival collections continued to be in heavy demand for both Institute-related activities and outside scholars. In particular, there was much activity in support of the Institute's involvement in the Department of Justice antitrust case. Among the major accessions, in addition to the Registrar's files, were the files of Walter Milne who retired in 1991 after many years as Assistant to the President and to the Chairman of the Corporation. Records were also acquired from Project Athena, the Chemical Engineering Practice School, and the Office of the Dean for Undergraduate Education, the last being the files of the late Margaret MacVicar. Two new manuscript collections were created: the Horatio Bond papers document his career as an expert on fire protection and consultant; the papers of Daniel Lerner cover a long career at the Center for International Studies focusing on European security.

ADMINISTRATION

Development and space planning were the focus of major new initiatives in the Libraries during the past year. Considerable effort was devoted to the creation of a current database of library donors with the objective of increasing communication with this group. The Director and Associate Director for Administration made joint presentations to the National Campaign Office and the Alumni Association. Three new endowed book funds were established during the year: the Ethel and Bernard Lippman Memorial Fund in physics; the Robert B. Newman Fund for Visual Collections in Building Technology; and the Elmer A. Skoberg Book Fund for reference works in engineering. In addition, the Class of 1982 designated the Music Library as one of the recipients of their tenth reunion gift.

The Libraries began to engage the issue of long term space planning with the appointment of an Ad Hoc Committee for the Hayden Library Building. Their charge is to develop ideas for improving the use of the building over the next ten years. A next step will be to work with the Planning Office in creating a long term vision for library space in the 21st century that is integrated with major campus development plans.

The Administrative Services staff were intimately involved in the renovation of the technical services area in Hayden Library as well as in general space planning and document delivery. They also led the investigation into accounting and auditing issues connected with the implementation of the automated acquisitions system. The Microreproduction Laboratory saw the first full year of the University Microfilms thesis abstract publishing program and continued to work with new electronic scanning hardware and software.

COLLECTION SERVICES

The planning effort begun in 1990/91 for the renovation and refurbishing of the technical services area on the second floor of Hayden Library was completed in the spring of 1992 and construction began immediately following June commencement. The excellent work of the Planning Group, that was recognized by Library Council as noted above, not only produced a fine program for the use of the space but also a plan for the temporary deployment of staff during construction. During the summer months of 1992, staff from Bibliographic Access Services and Serials and Acquisition Services are located in a variety of spaces, primarily

public reading areas, in the Humanities and Science Libraries. The project is scheduled for completion before the beginning of the fall semester.

The reduction of the size of the pre-cataloguing collection was a major achievement in Bibliographic Access Services and, as was noted earlier, was recognized by a Library Council Achievement Award. Significant progress was made also in the area of retrospective conversion of manual bibliographic records to machine-readable form. Conversion of 132,500 monographic records for the period 1965-1974 was completed on schedule as was the conversion of MIT theses for the same period. On July 1, 1992 work began to convert MIT theses for the period 1945-1963 and serial records for the period 1965-1974.

Implementation of an automated acquisitions system was undertaken in earnest with the formation of groups to deal with both the accounting issues and with system implementation. When it is implemented in the fall of 1992, the new system will reduce the amount of labor involved in typing and filing orders, will provide better fund accounting and invoice management, and will provide the Libraries with an opportunity to have hands-on experience with automated acquisitions in anticipation of a new library operating system coming in 1994.

A wide ranging and intensive study was undertaken to look at the feasibility and implications of electronic journal subscriptions. Based on the recommendations of a staff task force, the Libraries are developing a set of policies and procedures for dealing with this new form of scholarly communication. Subscriptions have been placed for four electronic journals: Electronic Journal of Communication/La Revue Electronique de Communication, Postmodern Culture (a journal of interdisciplinary studies), and Psychologuy (a journal sponsored by the American Psychological Association). All of these are peer reviewed journals. The Libraries in conjunction with Information Systems, is experimenting with the WAIS (Wide-Area Information Server) system architecture as the platform for mounting the full text journals.

The work funded by the National Endowment for the Humanities preservation microfilming grant was completed ahead of schedule. Over 1.3 million pages from late 19th and early 20th century journals in the history of technology were filmed in less than two years. Use copies of the film will be loaned to other libraries and MIT patrons on request. The master film will be stored under archival conditions.

Further physical and environmental work was undertaken in the RetroSpective Collection building that houses most of the Libraries' older materials. Electric door openers were installed in the delivery bays, and two potential fire hazards -- an oil tank and the old oil furnace - were removed. The new air conditioning equipment has performed well, resulting in a stable humidity/temperature situation. The large scale transfer of books and journals to the RetroSpective Collection continued, along with the transfer of additional material to the Harvard Depository.

There were some building "disasters" during the year. Water used to extinguish a fire on the fourth floor of Building 7 caused extensive damage to the carpeting and some minor damage to microfiche in Rotch Visual Collections. In Building 14 there continued to be serious problems with leaks from air conditioning equipment and from the cooling tower in the penthouse. A rupture in a steam line in the basement of Building 14 required the shutting down of the Computer Room for an extended period of time.

Other highlights in the Collection Services arena include: expanded efforts in soliciting copies of technical reports and other publications from MIT academic departments and research centers; a contractual arrangement with Engineering Information to provide copies of tables of contents of new engineering conferences and symposia for inclusion in their electronic database "Ei Page One"; dramatic growth in the number of United States government documents received in electronic form; and the beginning of discussions with library counterparts at Harvard and Yale regarding possible cooperative undertakings in collection development and long term storage.

Among the donors of major gifts of materials to the Libraries were Nesmith C. Ankeny (mathematics), Paul Barrett (architecture and building), Evsey D. Domar (economics), Harold Freeman (economics), Bernard J. Frieden (urban planning), Cavas Gobhai (health), Stanley Klein (computer software and books on computing), Richard C. Larson (criminal justice), Irving M. London (health sciences), Zella Luria (the personal library of Salvador E. Luria in the biosciences), Louis S. Osborne (physics), Walter A. Rosenblith (social and health sciences), Gian-Carlo Rota (mathematics), Victor F. Weisskopf (history of science), and Roy E. Welsch (management).

PUBLIC SERVICES

Much of the investigative work of the Information Services Study, aimed at documenting the current information seeking behavior of three MIT academic departments, was undertaken during the year. The purpose of the study is to learn how faculty, researchers, and students in Brain and Cognitive Science, Materials Science and Engineering, and Management currently identify and obtain information, the impact of technology on those processes, and the current and future role of the Libraries. Data gathering took place in four forms: (1) a "critical incident" questionnaire; (2) follow-up interviews; (3) focus group discussions; (4) reports on results discussed with the academic departments. A full report on the study will be issued during the 1992/93 academic year.

Electronic library services were greatly enhanced during the year with the implementation of OWL (Online with Libraries) reference service. Members of the community are able to send information and reference queries to the Libraries using a menu and format mounted on the campus network. The "Library Locker" on Athena was completely revised and a new prototype menu made available. This front end provides much more extensive information and, in many cases, actual services. When fully implemented it will point to library information on TechInfo; provide direct access to OWL, Barton, and other catalogues and services on the Internet; provide access to electronic forms for suggested purchase, interlibrary borrowing, Microreproduction Laboratory orders, and literature search requests.

Access to the Boston Library Consortium's union list of serials and to the complimentary table of contents databases - UnCover - is also included on the locker menu. Resources available to the MIT community through the Boston Library Consortium will be enhanced by the new membership of the libraries of the Marine Biological Laboratory and Woods Hole Oceanographic Institution. The BLC received a grant through the State of Massachusetts Board of Library Commissioners for installation of an interlibrary document delivery system using electronic scanning and the ARIEL software developed by the Research Libraries Group.

The Libraries' staff provided orientation sessions for new faculty and teaching assistants, freshman advisors, new graduate students, incoming freshmen, new

international students, and minority undergraduate students. Subject-focused instruction was also delivered to various undergraduate and graduate classes. Some examples are: space systems engineering, physics of semiconductors, biotechnology, marketing, research on the family, management of technology, anthropology, women's studies, art history, building design, and real estate development. The "liaison" concept that was successfully incorporated into the large undergraduate subject in psychology was extended last year to the Introduction to the History of Science subject in the Concourse program.

An innovation in library services was the decision to change from print to electronic form the Accessions Bulletin of the Industrial Relations Section. Long recognized as the most important publication of its kind in the field, the bulletin is subscribed to by faculty and research groups in many universities and colleges. The loss of outside financial support for paper publication promoted a review of the program and resulted in a decision to switch to an online medium.

The Computerized Literature Search Service, at the behest of the office of the MIT President, was able to bring together a number of interested parties who agreed to support access to a new, comprehensive database that covers federal legislation on a very current basis. Among the users of Legi-Slate, are the MIT Washington Office, the Office of Sponsored Programs, and the Libraries.

Among other public service activities during the year were the publication of a revised version of book handling and preservation guidelines for new staff; a National Library Week celebration that included a book sale, online demonstrations, and exhibits; a Term Paper Clinic implemented as part of the Psych Liaison Program; and "Library Days" -- a program on academic libraries presented to Boston and Cambridge high school students.

SYSTEMS AND PLANNING

Since the installation of the Geac 8000 system in 1986, Library Systems has seen its scope of responsibility increased to cover microcomputer operations, local area networks, and documentation and training for a variety of electronic services in the Libraries.

CD-Barton has clearly been a success. The power and capacity of a microcomputer-based CD-ROM product coupled with access to a circulation status file provides a first-rate catalogue for the MIT community. In cooperation with Marcive, the system vendor, the requirement for biweekly updates has been fulfilled. In June, 1992, Systems and Marcive completed the first re-mastering of the database.

On the Geac 8000, a number of changes have resulted in the ability to load more records at a faster pace. Primary were the installation of a new Exobyte tape drive and the full implementation of CD-Barton. In addition, the Geac version of Barton, the one that is available through dial access and on the campus network, is still available 24 hours per day but requires only a single version to be running rather than two, as in the past.

During the year, Systems planned and carried out the installation of 24 MIT network drops. These are used for public access to Athena, and for the distribution of circulation status files for CD-Barton. Seven Lantastic local area networks were installed during the year to support 26 workstations for CD-Barton. Systems conducted network training sessions and published the MIT

Libraries Guide to Athena containing specific information for use of Athena by Libraries' staff.

From June 1991 through May 1992, the number of catalogue records added to the online catalogue was 83,000, with over 122,000 item records added to the circulation database. By the end of FY1992 there were over 615,000 records in the catalogue, and over 750,000 in the circulation database. The total number of patrons with barcodes increased by 2,000 to a new total of 32,900. All of these figures attest to the growth in size and complexity of the online system.

DLI (Distributed Library Initiative) Activities for Systems included collaboration in the implementation of the network-based BRS search engine for access to Medline and Barton. Systems is also implementing the Z39.50, machine-to-machine information retrieval protocal for BRS.

AFFIRMATIVE ACTION

The Libraries completed six national searches for librarians and other academic staff members in FY1992. Four women were appointed as a result, but no new minority staff members were appointed. There are currently five minority professional staff members, representing 6.3% of the total staff.

The affirmative action search plan was revised at the end of the year, and as a result, additional minority recruitment sources were identified.

JAY K. LUCKER

LINCOLN LABORATORY

Lincoln Laboratory is operated by MIT as a Federally Funded Research and Development Center for performing research and development in advanced electronics. During the past year, agencies of the Department of Defense (DoD) -- namely, the Air Force, Army, Navy, and the Defense Advanced Research Projects Agency (DARPA) -- supplied approximately 90 percent of the Laboratory's budgetary support. The Federal Aviation Administration provided most of the non-DoD support. In fiscal year 1991 the operating budget was $377 million, supporting the efforts of 845 technical staff, 83% of whom hold advanced degrees.

The following administrative changes occurred at the Laboratory Steering Committee level during the year: Mr. Alan J. McLaughlin was appointed Assistant Director; Dr. Charles W. Niessen became Head of the Computer Technology Division; Dr. Darryl P. Greenwood was promoted to Head of the Optics Division; and Dr. David L. Briggs was appointed Head and Mr. Lee O. Upton Associate Head of the newly formed Air Defense Technology Division.

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

SURVEILLANCE TECHNOLOGY

Space-Based Visible Sensor

Lincoln Laboratory has been engaged in the development of technology and techniques leading to the potential deployment of space-based electro-optical sensors for space surveillance. These sensors would add significant capability to the current ground-based sensor network. The concepts being pursued require optics with high straylight rejection performance, focal planes in IR and visible band, and signal processing technology to provide real time target detection and clutter cancellation.

In order to demonstrate the concept and technology, Lincoln Laboratory is building the Space-Based Visible (SBV) sensor to be flown on the Midcourse Space Experiment (MSX) satellite in late 1993 for space demonstrations. The SBV sensor, operating in the visible wavelength, uses Charge Coupled Device (CCD) focal planes made from high sensitivity, high pixel density CCD chips. These chips, fabricated at Lincoln Laboratory, are the best currently available for low background applications. The SBV sensor also includes the signal processor with algorithms to provide automatic target detection and star cancellation, and the experiment controller to provide command/control of the sensor.

Near Earth Assessment Radar (NEAR)

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

NOAA Sensors and Spacecraft Program

As part of the weather service modernization program, NOAA is developing a new series of Geostationary Operational Environmental Satellites (GOES). A program was initiated in FY92 to support NOAA in their development of the GOES meteorological instruments, the spacecraft and related systems. In FY92 emphasis is placed on support to the GOES contractor to ensure delivery of the first flight model, GOES I. This support includes a performance assessment of the HgCdTe detectors, development

of EMI/ECM tests, evaluation of test data flows, electronics design and assessment of on-orbit radiometric performance through modeling of the response of the detectors, electronics and system throughput. Periodic summaries of program status are provided to the GOES program office.

Optical Discrimination Technology

During the past year, Lincoln Laboratory has utilized the Firepond Optical Research site in Westford, Massachusetts to observe a number of targets in space with both passive optical sensors and laser radars. Earth satellites and dedicated targets launched on sounding rockets from NASA's Wallops Island Flight Facility in Virginia were employed. The long-range imaging carbon-dioxide laser radar was able to observe changes in size, shape, and motion of objects deployed from the sounding rockets. Passive optical sensors provided a high-precision angular track of objects, while a visible-band neodymium radar provided precision range to the target; the combination allows rapid, precise target trajectory information to be generated. These successful measurements demonstrate the ability to track and identify objects using laser radar, a capability important for ballistic missile defense.

SATELLITE COMMUNICATIONS

Laser Satellite Communication

A concept for modular design of satellite optical crosslink packages has been developed. The concept uses fiber-optic technology to interconnect separate transmit, receive and pointing and tracking modules. This modular concept could significantly reduce optical crosslink package complexity and deployment cost because it provides an open architecture which allows development and upgrading of optical crosslinks as a collection of subsystems instead of as a single system of highly interrelated components. This concept grew out of a combination of Lincoln work with emerging optical fiber technology and Lincoln experience in space qualifying a number of optomechanical units.

Data rates above 1 Gigabit per second (GBPS) are significant potential applications for optical communication technology either in free space crosslinks or in terrestrial single-mode optical fiber links. Lincoln has developed several components for such high rate optical links. First, Lincoln has developed a 1 Watt semiconductor diode "laser" operating as an optical amplifier in a tapered waveguide configuration. This tapered amplifier has been used in an optical heterodyne communication link operating at 1 GBPS. The basic tapered amplifier device technology can also be used to produce laser diodes for pumping fiber-based optical amplifiers for emerging long-haul optical fiber communication systems. Second, Lincoln has cooperated with a commercial supplier to develop a high-speed optical waveguide modulator. This modulator has been used as an external modulator operating on the output of a diode laser to demonstrate heterodyne optical communication at 3 GBPS with DPSK modulation. Third, Lincoln has developed photodetectors with 10 GHz response bandwidths which are also capable of handling the high incident optical power required for heterodyne optical detection.

Lincoln and MIT campus groups have recently formed a consortium with two industrial partners to develop technology for advanced high data rate all optical ground networks with DARPA funding. These networks can provide crucial links connecting terrestrial military telecommunications and data processing systems with military space systems to support more timely dissemination of information and coordination of operations.

Satellite Communications

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

features and technologies into its Milstar system, which is being designed to carry the government's most critical strategic and tactical command and control communications.

Lincoln's technology program is currently concentrating on the complementary objectives of providing interference-resistant service at significantly higher channel data rates (>1 Mbps) and developing components and subsystems for very efficient implementations. The Laboratory's activities will support the government's mid-1990's decisions concerning modernization of the Milsatcom Architecture. The technologies which are key to achieving the above goals include adaptive antennas, lightweight signal generators, low-power signal processors, and reliable, efficient transmitters. Using ultra-lightweight waveguide and feed-horn technologies, a compact, high performance multiple-beam-antenna which can adapt its pattern to discriminate against interference sources has been realized at less than one-quarter of the weight of current implementations. An antenna configuration with a variable beamwidth capability to accommodate changing geographic user distributions is currently being pursued.

Lincoln has also developed a prototype EHF small man portable terminal (called the Advanced SCAMP) which weighs less than 30 pounds and will support protected single channel communications at voice rates with the FEP or Milstar systems. The Army has initiated an industrially-based terminal development based on the Laboratory's Advanced Scamp results. In addition, Lincoln is addressing technologies which are key to the implementation of a highly transportable, medium-data-rate (>1 Mbps), EHF terminal.

AIR TRAFFIC CONTROL

Terminal Air Traffic Control Automation

Air traffic congestion and delay continue to grow with increases in civil air traffic. The FAA plans to enhance safety, reduce controller work load, and increase capacity by developing automated planning aids for the controllers responsible for terminal airspace. This automation will help coordinate and schedule arrivals and departures and will suggest control actions for aircraft to help them comply with the schedule.

Lincoln Laboratory is working on this program in collaboration with NASA Ames Research Center. Lincoln has the responsibility for detailed system engineering of an initial set of aids for a near-term operational implementation by the FAA. Lincoln has the specific responsibility for developing interfaces to existing ATC equipment to extract the necessary surveillance, flight plan, and weather data and to enable the controllers to interact with the automation through existing radar display terminals. This interface work has proceeded well this year. All critical technical milestones have been met and the Lincoln interface system will be ready for the initial operational evaluation of TATCA automation aids planned for the Denver Airport in April 1993.

Airport Surface Traffic Automation

An increased incidence of surface accidents and runway incursions at major airports has led the FAA to develop surveillance and computer automation aids to improve the safety and efficiency of airport surface traffic control.

Work at Lincoln Laboratory this year has continued on the design of a processor for a modified X-band commercial marine radar that is being used for airport surface surveillance. This processor will provide digital outputs appropriate for driving automatic signaling and alerting logic. Examination of historical runway accidents and incidents has helped establish priorities for implementation of the logic necessary to reduce human errors and prevent runway incursions. Detailed analyses also have helped design logic with the proper trade-off between detection effectiveness and false alarms. The immediate goal of the program is a live demonstration at Boston Logan Airport in January 1993 of a system of automatic runway status lights for informing pilots when runways are not safe for entry. The system also will inform pilots preparing for takeoff when the runway ahead is not

safe. The demonstration system will be located in the Logan tower building in a room below the tower cab. The operation of the status lights will be demonstrated via a lighted scale model of the airport and via computer displays representing existing surface radar and approach airspace situation displays.

Aviation Weather Detection and Prediction

A multi-year program to improve the Federal Aviation Administration's capability to detect and predict weather conditions impacting aviation utilizes testbed radars and advanced signal and data processing to automatically provide weather information for air traffic controllers, pilots and air traffic control automation systems. The Laboratory has developed wind shear detection and storm motion algorithms that will be utilized in the Terminal Doppler Weather Radar (TDWR) to be deployed at major airports starting in 1992. When combined with suitable signal processing techniques to estimate low-altitude Doppler velocity, these algorithms enable the FAA's Airport Surveillance Radars (ASRs) to be equipped with a Wind Shear Processor (WSP), providing similar wind shear warning capability at the nation's smaller airports.

Measurements and operational demonstrations with testbed TDWR and ASR-WSP systems have taken place in a number of different locations. The TDWR testbed has conducted successful operational demonstrations at Denver, CO, Kansas City, MO and Orlando, FL. The Laboratory has provided technical support to the FAA leading to the procurement of 45 TDWRs. The ASR-WSP testbed has been operated in Huntsville, AL, Kansas City, MO and is currently being used for its third year of operational testing in Orlando, FL. Algorithm refinement is ongoing and acquisition of approximately 60 WSPs by the FAA is slated to begin in 1995.

An Integrated Terminal Weather System (ITWS) is being developed to improve delineation of hazardous airspace and to provide short-term forecasts of significant aviation weather parameters such as winds, visibility and ceiling. The Laboratory is developing the ITWS algorithms that will utilize data from FAA and National Weather Service systems such as Doppler radars, surface weather stations, thermodynamic "soundings" downlinked from aircraft descending into air terminals, lightning mappers and numerical forecast models. Technical support to the FAA is facilitating an aggressive program that will lead to an Initial Operating Capability for ITWS in 1996, followed by algorithm refinements and additions supporting full capability by the year 2000.

Critical Mobile Target Program

The Lincoln Laboratory Critical Mobile Target Program, sponsored by DARPA, is developing improved techniques for the detection and recognition of stationary vehicles by airborne radars. Much of the data used in this study was collected by the MIT/LL Millimeter Wave Airborne sensor, a 33-GHz, fully polarimetric synthetic aperture radar (SAR) with a 0.3 m resolution. In the past year, new algorithms have been developed, tested, and compared, and new insight has been gained in the benefits of polarization and high resolution.

Also, we are investigating the performance of low-frequency SAR in detecting targets which are hidden under trees. An experiment was conducted jointly by MIT Lincoln Laboratory and Jet Propulsion Laboratory in July 1990 using the NASA/JPL airborne SAR system, to investigate the phenomenology of foliage penetration SAR. A large number of 8-ft. corner reflectors were deployed for the investigation of two-way propagation through foliage, and tone generators were deployed to investigate one-way pulse-to-pulse phase amplitude fluctuations to study possible SAR beam distortions caused by trees. In addition, a 40 km^2 area was imaged over five passes at each of 30^o, 45^o and 60^o depression angles, simultaneously at C-, L-band and UHF frequencies, fully polarimetrically. Analysis of the data is near completion. Results indicate that there is significant penetration of the tree cover, and SAR resolution is fairly preserved particularly in the L-band and UHF frequencies. However, signal returns from the covered targets are generally no greater than those

from speckle due to tree clutter in a single-look image. Multiple-look processing reduces speckle and improves target to background contrast.

ELECTRONIC DEVICES

CCD Neural Network Processor

Since 1987, Lincoln Laboratory has been developing high-speed, low-power neural network processor chips based on charge-coupled-device (CCD) technology and a time-multiplexed parallel-pipelined computation architecture. These circuits share common features such as large numbers of computation elements, digitally stored connection weights and serial input/output buffers. In particular, a neural net classifier chip providing 3.8 billion computations/s and 6K synaptic weight storage has been developed. A neural net feature extraction chip capable of performing real-time two-dimensional operation has also been developed and is being integrated into a VMEbus-compatible circuit board. Applications for this board could include pattern recognition for radar, sonar, speech and image processing. Work has been initiated to develop a neural net chip capable of providing 10 billion computations/s and to insert a number of these chips into a VMEbus-compatible board. The board is to be used for applications such as speech recognition, data fusion, automatic target recognition, sonar signal identification, and neural net algorithm performance measurements including learning capability.

Mid-Infrared Diode Lasers

High-performance diode lasers capable of room-temperature operation in the mid-infrared region (wavelengths between 2 and 5 μm) would be useful as eyesafe sources for a wide variety of important military and civilian applications, including laser radar, target illumination and designation, remote sensing of atmospheric pollutants and toxic gases, molecular spectroscopy, wind shear detection, and medical and dental surgery. Using structures composed of GaSb-based alloys, Lincoln Laboratory has demonstrated room-temperature diode lasers emitting at about 2 μm with differential quantum efficiencies of 70% and continuous output powers of 0.4 W, by far the best values obtained for any mid-infrared lasers. These devices are already comparable in performance to the lasers at shorter wavelengths that are used for optical fiber communications. Structures employing different alloys in the same material system have the potential for emission out to 5 μm. In initial experiments on lasers emitting at 4 μm, pulsed operation has been achieved at temperatures up to 155 K.

GaSb-based alloys also have a potential for infrared detectors. In particular, their use for low-noise avalanche photodiodes in the 1-to-3-μm wavelength range is currently being explored.

MACHINE INTELLIGENCE TECHNOLOGY

Knowledge-Based Systems Technology for Communication Networks

Three expert systems projects have been undertaken in the area of managing and controlling communications systems. Two of them have been brought to the point of technology transfer: an Air Force system for fault diagnosis and service restoral of dedicated circuits, and a Defense Information Systems Agency system for Management of the DoD telephone system. In FY91 and FY92 work commenced on the third, an expert system for interpretation of fault alarm patterns in a microwave communications network. Work is progressing on the integration of these three synergistic systems in the operational military communications environment.

MX-2: An Optically Interconnected Multiprocessor for MI Applications

Efforts are underway to develop a second generation shared memory multiprocessor for real time machine intelligence (MI) applications (MX-2), using RISC microprocessors and free-space optical links for high speed, low latency interprocessor communication. A demonstration system was completed this year which coupled two clusters of RISC processors (Motorola 88000s) with free-space optical links transmitting data at 1 Gigabit/second. The reliability of the links is extremely high, with a measured bit error rate of less than 1 in 10^{12}. Error detection coding was included in the links. The next phase of this program is to build and

demonstrate a ring network comprising 4 to 8 nodes using free-space optical links to transmit at 4 to 8 Gigabits/second between nodes.

DIGITAL INTEGRATED CIRCUITS

Molecular Structure of Hot-Carrier Induced Defects in MOSFETs

To increase the speed of integrated circuits, higher electric fields are being used, which result in damage at the silicon-oxide interface, degrading the device. Using a new spin resonance technique, it was demonstrated that the principal damage is the P_b center, well known from radiation studies to be a Si atom bonded to three other silicons, with a dangling bond extending into the oxide. This identification allows the knowledge developed in radiation hardening to be applied to the problem of increasing resistance to hot carrier damage.

Laser-Programmed Multichip Module

Multichip modules (MCMs) allow greatly increased density and speed by reducing packaging volume and the length of interconnections, but custom design and fabrication of MCMs are time consuming and extensive. To make the technology available for prototype systems, a new approach has been designed in which a standard substrate, which can be mass produced, is customized in a short time and at low cost by the use of laser links and cuts. This approach builds on both the laser link technology and the design tools developed in previous years in Lincoln's monolithic wafer scale integration program.

SPEECH SYSTEMS TECHNOLOGY

Large-Vocabulary Continuous Speech Recognition

A large-vocabulary continuous speech recognizer has been developed. This system has been demonstrated using a 64K word vocabulary, but is generally used with 5K or 20K word vocabularies. It consists of an acoustic front-end, a hidden Markov model (acoustic) trainer, a stack decoder controlled hidden Markov model recognizer, and a recognition language model. The recognition system can use any stochastic or non-stochastic left-to-right language model, and can be operated in speaker-dependent or speaker-independent modes. Good performance has been demonstrated on a variety of tasks, including the DARPA Resource Management Database (1000-word vocabulary), and the DARPA Wall Street Journal Database (5K and 20K word vocabularies).

Multi-rate Speech Coding for Digital Radio and for Voice Conferencing

The Lincoln Laboratory Sinusoidal Transform Coder is a speech compression technique that has produced synthetic speech of high quality at rates from 2400 b/s to 4800 b/s. It is currently one of the leading candidates for selection as a speech coding standard for the half-rate digital cellular communications system which is being specified by the Telecommunications Industry Association. The MIT Technology Licensing Office has arranged for the transfer of this technology to AWARE, Inc. in Cambridge for the development of the digital cellular application and to COMTECH in Palo Alto for the development of a secure videophone.

NEURAL NETWORK TECHNOLOGY

Neural Networks for Speech Recognition and Pattern Classification

Radial Basis Function (RBF) classifiers have been incorporated in a hybrid isolated-word recognizer which uses hidden Markov model (HMM) algorithms for training and testing, resulting in good performance on a difficult alphabet recognition task with fewer trainable parameters than required by more conventional approaches. Neural networks were then used to discriminate between true hits and false alarms provided at the output of an existing HMM wordspotter, reducing the false alarm rate of the HMM wordspotter by roughly 16%. The RBF classifier and more than 16 other neural network and statistical pattern classification algorithms have been included in a sophisticated software package called LNKnet. LNKnet provides a high-level simple-to-use graphical user interface and a uniform low-level subroutine interface, and is currently in use at Lincoln Laboratory and five other government laboratories.

Artificial Neural Networks for Object Recognition

Interconnected systems of artificial neural networks are being developed to detect and recognize three dimensional objects in visual and synthetic aperture radar images. The research emphasizes unsupervised learning of representative object views, learning of view transitions, and recognition based on the learned views and transitions. An experimental end-to-end system has been implemented in software, incorporating networks for object detection and feature extraction, overlapping receptive fields for course feature coding, Adaptive Resonance Theory networks for view learning and recognition, multi-view Aspect Networks for learning and recognizing view transitions, and a final stage which performs recognition on the basis of evidence accumulated by the Aspect Networks. Experimental demonstrations have been carried out with visual images and with inverse synthetic aperture rate data.

SENSOR PROCESSOR TECHNOLOGY

Space-Qualified Signal Processor

A space-qualified signal processor has been developed for the Space Based Visible (SBV) instrument scheduled to fly on the SDIO-sponsored Mid-course Space Experiment (MSX) satellite in 1994. The processor accepts data from Laboratory-built CCD chips at a rate of 0.5 million pixels per second. Using adaptive filtering concepts, the processor suppresses background clutter and generates target reports. The processor can report metrics (position, velocity) of detected streaks, and signature (amplitude) data. It also provides guide star information to derive the sensor pointing angle, and formats the reports for inclusion in the telemetry downlink stream. The processor consists of two fully redundant channels, each using a Motorola DSP56001 digital signal processing chip, which offers a 10 MOPS instruction rate or 20 MOPS arithmetic throughput. The signal processor will weigh about 12 lbs, dissipate about 10W, and occupy about 350 in^3.

STRATEGIC DEFENSE PROGRAM

Measurement Range Integration

Lincoln Laboratory provides the scientific direction for all data collection sensors at the Kwajalein Missile Range in the Marshall Islands. One of the first steps toward integrating the forty sensors, which include radar, optical, and telemetry equipment, is the configuration of the Kwajalein Missile Control Center (KMCC). The Laboratory has begun the large computer software/hardware effort to establish this center on Kwajalein Island and to network all sensors together so that the exchange of control, signature, and tracking information can be accomplished in real-time during a mission at the Range.

Optical Airborne Measurements

As part of the program managed by the U.S. Army Strategic Defense Command, Lincoln Laboratory has been responsible for the design, acquisition, integration, operations and maintenance, and data reduction for a dedicated, high altitude, airborne data collection system. A multiband infrared telescope views out of the right side of an USAF RC-135 aircraft. The telescope and sensor electronics collect and record exoatmospheric and endoatmospheric data on space and ballistic missile reentry objects. The aircraft/sensor system is operated by U.S. Air Force crews. During a typical mission, initial pointing information is received from a ground-based radar, coupled with aircraft navigation data and the sensor inertial reference unit, to provide target acquisition. If radar data are not available, preplanned search techniques are used to acquire targets. The aircraft became fully operational in March 1990 and has collected a significant quantity of high quality measurement data used in research vital to ballistic missile defense.

Super Range Resolution

Linear frequency modulation radar waveforms are used to achieve high range resolution by matched filter pulse compression. Typically, the modulation bandwidth is approximately 10 percent of the radar frequency. Thus, for example, at S-Band (3000 MHz), approximately 90 cm range resolution can be obtained. Recently, by

applying modern spectral estimation methods to the received spectral data prior to pulse compression, the effective bandwidth can be expanded. This is achieved using autoregressive fits to the measured data, and linearly extrapolating the data beyond the measured spectrum. Subsequent pulse compression then yields data with approximately three times better range resolution. Because the data are linearly extrapolated, the coherent properties are preserved. Doppler processing using inverse synthetic aperture (ISAR) methods then yields two dimensional images with significantly improved resolution.

ADAPTIVE OPTICS FOR ASTRONOMY

There is continuing interest in the astronomical community in the use of adaptive optics for compensation for atmospheric turbulence effects on imaging. This technology was developed under Defense Department sponsorship and has been made available for civilian use as a result of a program declassification.

At present, Lincoln is supporting the transfer with two systems: the 241-channel "SWAT" system at the MIT Firepond site (installed on a 1.2 meter telescope), and the 69-channel "ACE" system installed on the Mt. Wilson 60-inch telescope. Results should be forthcoming from both sites in the coming year.

WALTER E. MORROW, JR.

SCHOOL OF ARCHITECTURE AND PLANNING

In the past year the School of Architecture and Planning experienced transitions in major areas through processes involving reflection, planning, and change of leadership.

The Provost announced the appointment of William J. Mitchell as the new Dean of the School effective July 1, 1992. Also effective July 1 was the appointment of Professor Philip Clay as head of the Department of Urban Studies and Planning. Professor Stanford Anderson completed his first year as head of the Department of Architecture. Four senior faculty retired, effective July 1. Professors Donald Schon, Maurice Smith, and Imre Halasz will continue to teach in the School. Professor Frank Jones will take up new opportunities in Atlanta.

Academic and Research Programs

The Department of Urban Studies and Planning completed its long range plan under the leadership of the department head, Professor Donald Schon. Implementation of the plan has begun and will continue to be a prime focus of energy for the department over the next few years. Financial support of graduate students in the department, a characteristically acute problem, was made somewhat easier during the year by the success of the department's intern program with cooperating firms, non-profit organizations, and government agencies. Professor Frank Levy, a new appointment, will be the first holder of the Daniel Rose Professorship.

The Department of Architecture entered a period of redefinition under its department head, Professor Stanford Anderson, bringing to the architecture design and studies group a coherence of purpose and concept for its graduate degree programs. The efforts are hampered by the expedient but ultimately unsatisfactory division of departmental space into two separate clusters. Some reduction was made in graduate student enrollments to address the persistent shortfall in financial aid.

The Media Arts and Sciences Section prepared for an intensive summer study and retreat as a prelude to the forthcoming review of its academic directions. The section reached a steady state of between 80 and 90 in graduate students during the year, and hosted as well its usual large complement of UROP students. Professor Stephen Benton, the section head, was named the first holder of the Institute's Rudge '48 and Nancy Allen Professorship. The Media Laboratory increased its research support by 16 per cent during the year to an annual research volume of $8.6 million. This included strong interest from European sponsors.

The Center for Real Estate, despite continuing problems in the industry, sustained a very active program of activities and research, and student interest continues at a high level. Professor William Wheaton assumed directorship of the Center from outgoing director Professor Larry Bacow.

Preparations are underway to mark in the coming year the twenty-fifth anniversary of the Center for Advanced Visual Studies. At the same time, Professor Otto Piene has made plans for his retirement at the end of the coming academic year at which time the future of the Center will be reviewed.

Campaign

The School shared with MIT in the benefits of a successfully completed Campaign for the Future. Total support over the period of the campaign in the form of completed gifts and pledges for Media Arts and Sciences and the Media Lab was $24,138,981. For the remainder of the School the corresponding figure was $21,630,826. The latter figure includes several outstanding the gifts to the School: the Norman and Muriel Leventhal Professorship; the Daniel Rose Professorship; the Edward H. and Joyce Linde Career Development Professorship; the Blackall Career Development Professorship; Hank Spaulding, gift of $1 million to the Center for Real Estate; and Toda Corporation of Japan, gift of $1.25 million for research in building technology. The School also benefited from the centrally established Rudge '48 and Nancy Allen Professorship.

Facilities

The completion of the Rotch Library addition and renovation was marked with a special occasion in December to honor the senior MIT administration for their commitment to the rebuilding of the library. In the opening talk, historian Henry Millon, head of the National Gallery of Art's Center for Advanced Study in the Visual Arts, traced the relationship between the development of libraries and of architectural ideas.

Respondents were editor Roger Conover of MIT Press; librarian Angela Giral of Avery Library; and architect William L. Rawn, III, '79 MArch.

We continued to plan for the incremental consolidation of the Department of Architecture and the Department of Urban Studies and Planning at the core of MIT. The amount of space occupied by the School is not, in general, the issue. But the location and condition of that space are problems to be addressed in a serious way over the next ten years.

Community Outreach

In April the School held its second Northeast Mayors' Institute on City Design, supported by the National Endowment for the Arts. For the national meetings of the American Institute of Architects in June, the Department of Architecture hosted a symposium on architectural criticism. Concurrently the MIT Museum featured an exhibit of the MIT design faculty, entitled "Thinking the City," and an exhibit on William Ware and American architectural education.

Planning began for a major conference in 1993 on "Shaping the Livable Region". This effort, co-sponsored by MIT, Harvard, and the Boston Globe, will explore future regional transportation and development options in the wake of construction of the Central Artery and the Third Harbor Tunnel.

The School continued to plan educational experiences abroad, including workshops or studios in Poland, Beijing and Tokyo. Faculty explored the possibility of a future connection with the planning authority of St. Petersburg.

Community Composition

The School's total enrollment went from 615 to 600 students. Of this total 42 percent were women and 12 percent were underrepresented minorities. The figures for the departments were: Architecture with 40 percent women and 8 percent minorities; Urban Studies and Planning with 53 percent women and 22 percent minorities. The Media Arts and Sciences Section had 21 percent women and 5 percent minorities . The numbers of women and minority faculty members for the School increased slightly to 14 women and 5 minorities out of a total faculty count of 69.

Office of the Dean

The new Dean of the School of Architecture and Planning, William J. Mitchell, comes to MIT from his position as Professor and Director of the Master in Design Studies at Harvard Graduate School of Design. His arrival brings to MIT a distinguished scholar and practitioner with a rich vision about the future, which is relevant to all the School's fields of enquiry and practice.

John de Monchaux
Dean

FACULTY, OTHER ACADEMIC STAFF, AND RESEARCH STAFF -- 1991-1992

	1990-1991				1991-1992			
	Total	Full Time Equivalent	Women	Minority	Total	Full Time Equivalent	Women	Minority
Department of Architecture								
Faculty	26	26	4	0	31	30.5	6	1
Other Academic Staff	32	20	6	1	25	18	4	0
Research Staff	2	1.5	0	0	4	2.5	0	0
Without Pay	2	2	0	0	15	15	3	1
Department of Urban Studies and Planning								
Faculty	24	23	4	4	24	23	3	4
Other Academic Staff	16	11.4	8	3	22	18	9	1
Research Staff	2	1.75	-	-	6	4.5	2	0
Without Pay	11	7	7	3	9	6.3	5	0
Media Arts and Sciences Section								
Faculty	12	12	3	0	14	14	5	0
Other Academic Staff	4	3.2	1	1	5	4.2	3	1
Research Staff		0	0	0	0	0	0	0
Without Pay	1	.2	0	0	3	2.2	2	0
Media Laboratory								
Research Staff	33	31.87	7	1	40	37.95	11	1
Without Pay	15	15	0	0	13	12.2	1	0
School Totals								
Faculty	62	61	11	4	69	67.5	14	5
Other Academic Staff	52	52	15	5	52	40.2	16	2
Research Staff	37	35.12	7	1	50	44.95	13	1
Without Pay	29	24.2	7	3	40	35.7	11	1

STUDENT ENROLLMENT AND COMPOSITION 1991-1992

	Total	Women	Minority	International
Department of Architecture				
Undergraduate	94	50	12	6
M.Arch.	100	39	4	17
S.M.Arch.S.	42	13	3	29
S.M.Vis.S.	8	6	2	2
Ph.D. (resident)	14	7	1	8
S.M. Building Technology	3	0	0	0
Total Graduate Resident	167	65	10	56
S.M. Real Estate Devel.	34	6	3	4
Ph.D. (nonresident)	17	5	0	9
Special Students (nondegree)	0	0	0	0
ARCHITECTURE TOTAL	312	126	25	75
Department of Urban Studies and Planning				
Undergraduate	10	7	1	0
M.C.P.	75	43	16	21
S.M.Real Estate Devel.	18	4	1	1
Joint M.C.P./M.Arch.	15	9	2	6
Ph.D. (resident)	34	12	2	18
Total Graduate Resident	142	68	21	46
Ph.D. (nonresident)	22	14	5	7
Special Students (nondegree)				
SPURS	10	6	2	10
CFP	14	10	14	0
DUSP TOTAL	198	105	43	63
Media Arts and Sciences Section				
S.M. (unspecified)	38	9	2	5
Ph.D.	44	8	2	4
Special Students (nondegree)	4	1	0	1
MAS TOTAL	86	18	4	10
School Totals				
Undergraduates	104	57	13	6
Graduate	468	176	43	132
Special Students	28	17	16	11
TOTAL ENROLLMENT	600	250	72	149

Department of Architecture

The transition in leadership went smoothly as I began my term as Department Head in Architecture this year. The issue of who would succeed Professor William Porter was settled a full academic year in advance, and there had been ample opportunity, especially in work with a number of key committees, for me to assess and prepare for the challenges ahead. In November 1991 as one speaker in the department's public lecture series, I described the history and distinguished tradition of MIT's Department of Architecture and outlined my own hopes and intentions for its future course.

A number of important objectives had already been achieved. A wide-ranging search in the Architectural Studies area last year concluded in the appointment of two non-tenured and one tenured faculty person. Those appointments brought the total number of faculty slots filled in the past five years to seventeen (of a total 36 slots). We have reorganized the undergraduate curriculum, opened new master's and doctoral streams in Building Technology, and begun a hard look at advanced design teaching and professional program curriculum reform. The new Rotch Library is open after more than a dozen years' occupation of crowded inadequate space.

And a number of serious issues remained to be addressed--further renewal of faculty in the Architectural Design discipline area, reform of curricula, resolution of our divided facilities, and development of economic support for students and faculty foremost among them.

In the architectural studio faculty (those engaged in the core of the professional degree program and thus also the heart of the department), there is still a serious demographic imbalance: three tenured faculty (two of whom retired effective 1 July 1992), a group of young faculty, and only two relatively senior, tenured professors between. The next few years will be critical in determining whether stagnation or a major renewal of this crucial part of the faculty occurs. The academically atypical careers of young studio faculty makes tenure review particularly difficult for them. Given the large number of junior faculty still facing tenure reviews and the onset of retirements in the senior ranks, it is necessary in the coming year to open a search for two studio teachers--one untenured, one tenured.

Further, support for new and junior faculty that will hold them, allow them to thrive, and be effective members of a new generation that will inherit the department in the next decade must be developed and built into the department system. The intellectual and professional environment set, particularly by the Head and the Dean, must establish high standards and positive character for achievement, engagement, mutual respect, and collegiality.

Weaknesses and mistakes in curricula in both the professional (MArch) and advanced studies (SMArchS) programs are under analysis and revision; advanced design teaching urgently requires redefinition and coordination. Scrutiny of advanced studies teaching was begun this year; serious study and overhaul of the professional program will go forward next year.

Considered in relationship to both achievements and problems, the department's divided physical situation becomes even more discouraging. The division in two locations, remote from one another, and one of those peripheral to MIT, is destructive of educational and research programs. Our current division falls exactly where the difficult disciplinary splits typically occur in schools of architecture--i.e., the studio-based architectural education at our remote location (N51-52) while Rotch Library and technical, historic and urbanistic teaching are in the main complex. The strengths of discipline groups and the unique opportunities that they can create for the professional program are contravened every minute this arrangement persists. The Institute's reunification of this department in the main complex with our traditional orientation around Rotch Library is crucial for the revitalization of the department.

PROGRAMS

A total of 378 students, including Media Arts and Sciences and special students, PhD non-residents, and SM in Real Estate Development degree candidates were enrolled in Course IV this academic year.

The total enrollment of department students in residence was: 94 undergraduate BSAD candidates; 99 graduate Master of Architecture (MArch) students,39 SM Architecture Studies (SMArchS); 6 MS in Building Technology; 8 SM Visual Studies, and 13 resident PhD students.

BSAD

Undergraduate enrollment appears to have stabilized at 95-100 students each year. In the four years 1989-1992, the number of freshmen electing to major in Course IV has ranged from 28-33. Transfer students plus those electing later to major in Course IV yields the 95 to 100. (The number of undergraduates in the years 1987 through 1991 was higher than this, peaking in 1988-89 at 122). Of the 95 undergraduates registered in the department in October 1991, 61% are women, approximately 9% of the total undergraduates are underrepresented minorities.

Of the 34 seniors this year, 24 took the pre-professional, Architectural Design concentration, 3 Building Technology, 4 History, Theory and Criticism of Architecture and Art, and 3 Course IV-B (an individually structured curriculum). The breakdown by concentrations has not significantly changed over the past ten years. We anticipate some increase in concentrations in visual arts and building technology, as these concentrations become more visible. This is taking longer than we anticipated, but we still believe it will happen, but probably in small numbers.

MArch and SMArchS

Applications for admission to the professional MArch program sustained the increase begun last year--274 for a total of 26 places. The second master's degree (SMArchS) applications were still fewer than last year--82 for about 17 available places. The shifts are in part accounted for by a change in admissions policy last year, i.e., foreign and US applicants with prior professional degrees and primarily interested in design studio work, previously only admitted to SMArchS, were considered for the MArch program.

Enrollments increased this year in both programs because of the larger MArch pool (students who already had a first professional degree) and the addition of a new Theory and Methods group in SMArchS. (31 new MArch and 21 SMArchS students total.) However, the department cannot provide financial aid to this increased number of students and will enroll fewer students in both programs next fall (26 new MArch students and 17 SMArchS).

The SMArchS program has been reframed based on recommendations from a curriculum study done this year. 1992-93 will be a transitional year that largely establishes the program in a new form the following academic year. The newly framed program will be closely tied both to established and new areas of faculty research, with strong encouragement that students in this degree program be engaged in design studios and other synthetic research activities. This initiative is supported by new studio offerings and design professors.

There are continuities from the previous program: we continue to accept only a small number of qualified students; they work with a large and diverse faculty--potentially any professor of the department as well as other units at MIT and even other universities. Emphasis is on programs appropriate to each individual, and again, with new emphasis on synthetic design activities.

DISCIPLINE GROUPS

Architectural Design

This year Architectural Studies and Architectural Design, operated for the first time in many years as one discipline group, discussing the common future as custodians of the professional MArch and advanced studies (SMArchS) degree programs. Two major curriculum and governance committees operated through the year, composed of studio and advanced studies faculty, and admissions for MArch and SMArchS were handled by joint committees as well.

In fall 1991 the Advanced Studies Committee, chaired by Professor Julian Beinart, was formed and charged with examining "all post-professional education of the department centered on the newly extended definition of the architectural design discipline group". Instructions to the committee included the maintenance of concern for the well-being of the MArch degree program, the avoidance of identification of faculty with particular degree programs, and the continuation in post-professional education of research in architecture and urbanism with a renewed emphasis on design. The committee sought to define an amenable structure within which individual faculty members and research interest clusters can locate their work in order best to receive the support of their colleagues and MIT. Four areas of inquiry were identified as capable of hosting research and/or teaching initiatives, by virtue of faculty strength and prior commitment of significant funds available to the department or school. They are: Architecture and Culture (including Aga Khan Program resources), Architecture and Technology, Architecture and Urbanism, and Design Inquiry (including MIT and School commitments to computation and the Computer Resource Laboratory). Professor Stanford Anderson will convene an organizing session for each group to draw together interested faculty and collectively describe research and teaching initiatives.

Two searches conducted this year will have particular interest for advanced studies. One search, for an Assistant or Associate Professor in design and computation, chaired by Professor Leon Groisser, came to a final short list of candidates at the end of spring term. Followed almost immediately by the Institute's naming William Mitchell as Dean of the School of Architecture and Planning, the possibilities for development of computational resources in the Department and the School was enhanced exponentially. The Aga Khan Professor of Design for Islamic Societies chair continues to be searched; addition of that senior faculty person hoped for in January 1993 will be important as well.

In fall semester, 1991, with the impetus provided by Professor Jan Wampler, the design studio faculty began preparation of an exhibition of faculty work, to be mounted in the MIT Museum gallery. Many ideas for the joint production were discussed, and finally a challenge to make individual contributions to a common theme, "Thinking the City", was accepted. The exhibit was conceived as a short sketch problem in which the faculty would present some thoughts about design in the Boston context. Contributions were also thought of as an opportunity to organize ideas of the city generally. The exhibition became a first attempt by department studio faculty to make public their agenda for architectural investigations at MIT for the next few years. Twelve faculty members made individual contributions, and the exhibition was opened in February 1992 to remain on view at the MIT Museum through the summer.

Building Technology

All faculty, students and research staff in Building Technology moved together into temporary quarters in 4-209, formerly Laboratory for Architecture and Planning space. The interim move, which puts them into closer contact than even that congenial group prefers, was made to accommodate expansion of the Mechanical Engineering Design Center. Building Technology is slated to occupy new facilities in a renovated 10-485 complex. Progress on that space change has been difficult and slow.

Numbers of undergraduate students in the BT concentration remains relatively constant, and there is still interest within that group in establishing a joint BS in Building Technology degree with the Departments of Civil and Mechanical Engineering. This year there was an increase in the number of SM Building Technology applicants admitted, bringing the MS in BT program to full complement for the coming year. The two BT doctoral candidates have come from the master's program ranks.

Research in the group continues to build, focussing generally in three areas: environmental and engineering problems related to building; materials and systems; structures and construction. Among the projects: Professors James Axley and Les Norford, with graduate research assistants and undergraduate UROP students, worked on the Laser Light Sheet project, sponsored by Shimizu, to develop a system to make measurements of personal exposure to indoor air pollutants and the success or failure of clean room designs. Professor Norford this year concluded a two-year term as an advisor to the National Academy of Science on energy efficiency issues in eastern Europe. The Innovative

Housing Construction Technologies project culminated this year in the construction of a proof-of-concept house. Professors Leon Glicksman and Leonard Morse-Fortier and Research Associate John Crowley conduct this research with colleagues in the School of Engineering. The project is dedicated to exploring the combination of new materials with new design concepts in the construction of housing. It is supported by a consortium of sponsors (including this year Certenteed, Host Celanese), whose contributions over the last three years have averaged more than $250,000/year.

The department was very pleased to receive a major gift from the Toda Foundation, Tokyo, Japan. The funds will be used to develop the new facilities for Building Technology in 10-485 and serve as seed funds for research initiatives in a variety of fields, including indoor air quality, structural analysis of frame structures, and new thermal efficient materials for buildings.

History, Theory and Criticism of Architecture and Art

The HTC section completed a lively year marked by the contributions of a faculty more diverse than usual because of a large number of short-term and part-time appointments. Some new people were brought to the program with funds released by faculty on leave, and two--Professors Akos Moravánszky and Royston Landau, on longer-term appointments--came as replacements for Professor Anderson. The members of this group complemented each other, the long term faculty, and the interests of the student population remarkably well. They made a concerted effort to overcome the potential fragmentation of energy posed by the absence of some of the regular faculty by becoming highly visible in the program very quickly. Professors Moravánszky and Landau take their special responsibilities in the section extremely seriously. They spent long hours meeting with students and are increasingly being named as the formal advisors of HTC graduate students.

HTC continued to respond to the pull of many constituencies. This year exactly 100 undergraduates enrolled in HTC HASS-D subjects, creating a demand for teaching assistants that stretches resources to the breaking point. The number of concentrators continued to grow: 15 are registered to fulfill undergraduate concentration requirements in art and architectural history/theory; 9 have made the further commitment to minor in HTC. For the professional program in architecture, the faculty taught both foundation and platform subjects (in criticism of contemporary architecture and architecture and epistemology, respectively). In addition, Professor Francesco Passanti moderated the Friday noon Design Faculty Seminar which has been important in stimulating debate across the department.

HTC admissions broke all pattern this year. PhD applications were up 50%--to 59. Admissions were also up, despite an unimproved financial picture. A number of candidates who have gone to our competition at Harvard, Princeton, Berkeley and Cornell have told us they would have preferred to come to MIT but for finances. Despite this continued handicap, this year all but one of the top choices accepted our offers. In addition, four students, all excellent, will enroll with their own funding. The total of 8 is the largest incoming class in the PhD program's history. In SMArchS the situation is also unique, but less happy. For the first time only one HTC student was admitted and she was unable to accept for financial reasons.

Visual Arts

The Visual Arts program continued implementing its development plan, this year introducing video courses and expanding offerings in photography as well. Baldwin Lee (BSAD '72), on leave from the University of Tennessee, was Visiting Professor in Visual Arts and taught two subjects in photography and co-taught in the Visual Arts foundations subject. Peter Campus was a visiting artist who worked with our beginning and advanced students in photography. Valerie Maynard was also a visiting artist in March, lecturing and critiquing student work in a number of program subjects. Next year the internationally known artist and photographer, Krzysztof Wodiczko, will join the Visual Arts faculty as Assistant Professor. His appointment comes as a result of a search conducted in AY 1991.

Visual Arts faculty exhibited their work in a number of Boston shows. Professor Ritsuko Taho did an installation, "On the Path", at Main Gallery of Massachusetts College of Art, and Professor Levine installed a permanent work in the Margaret Roethelberger Park in Cambridge. Sharon Daniel had an

interactive video sculpture in the Women's Caucus juried exhibit, "Distinct Voices", at the Federal Reserve Bank Gallery, Boston, and an interactive video installation, funded in part by an MIT Council for the Arts grant, at the Brickbottom Artists' Studio Gallery in Cambridge.

FACULTY

Three new faculty members joined the department this year. Roy Strickland (MArch '82), formerly Associate Dean at Columbia University School of Architecture and Urban Planning; Sibel Bozdogan, from Rensselaer Polytechnic Institute, and Michael Dennis, who was most recently a member of the Cornell University faculty, as Professor of Architecture. These three were appointed from the search conducted last year chaired by Professor Beinart. Professor Moravánszky joined our faculty for a four-year term, replacing (in part) Professor Anderson in the HTC group. Professor Moravánszky, who had been at the Getty Center in Santa Monica in the previous two years, taught subjects at MIT in modern European architecture. Professor Landau, Head of the Graduate School at the Architectural Association, London, took up his appointment in the department this spring term. He too serves as partial replacement for Professor Anderson and will be a part of the HTC faculty each spring until 1995. He taught a subject titled "The Architectural Agenda: Historical and Theoretical Research" and a graduate seminar with Professor Bozdogan.

Professor Eric Dluhosch and Professor Wampler were promoted to the rank of full professor. Professor John Myer was on partial leave in the fall term; Professor Wellington Reiter was on leave in the fall; Professor Rosemary Grimshaw was on leave in the spring. Professor Benjamin Buchloh is on half-time appointment for this and next year, serving the balance of each year as Director of Critical Studies at the Whitney Art Museum in New York. Professor Frank Miller ends an appointment as Assistant Professor of Architecture and will remain in the department for a further year as Research Associate. Two of the new junior faculty who were first appointed this year, Professor Bozdogan and Professor Renee Chow, were given special Provost's grants of $15,000 each for five years to assist their scholarly work. Professor Stickland was given similar support from the Department budget.

Visitors to HTC were Ewa Lajer Burcharth, replacing Professor Leila Kinney who was on leave for the year; Yule Heibel replaced Professor Buchloh; Professor Passanti took leave in the fall term, and was replaced by a young scholar from Belgium, Hilde Heynen, who taught a seminar entitled "Critical Theories of Modernity and the Issues of Modern Architecture". Professor Klaus Herdeg, from the Department of Architecture, Columbia University, was Visiting Aga Khan Professor of Architecture at MIT this fall. He led a workshop for the Design for Islamic Societies section titled "Architecture and Urban Context: Tradition, Conflicts, Change." Shayne O'Neil, Assistant Professor on leave from the Department of Architecture at Cornell, was appointed to the studio faculty for one year and taught a Level III studio in the fall and at Level I in the spring. Charles Bradley (SMArchS '83) was Visiting Scholar working with Professor Sandra Howell in teaching and research in behavioral science in architecture. Mr. Bradley came to the department staff sponsored by a special School program for underrepresented minorities. Roswell Angier was a Lecturer in Visual Arts teaching a photography subject in the fall; Sharon Daniel was appointed for the year to teach video as well as in the Visual Arts foundation subject for undergraduates.

Faculty awards: Professor Reiter was awarded a Wheelwright Traveling Fellowship from Harvard and spent the fall term working and studying in Rome. Professor Nasser Rabbat won the Malcolm Kerr Dissertation Award in Humanities, awarded by the Middle East Studies Association. Chris Dewart, Technical Instructor in Architecture, was honored this year with the Graduate Student Council Teaching Award.

OTHER

Professor Anderson took personal responsibility for the department lecture series, inviting a list of distinguished speakers to offer talks around a general topic. The fall term series, "Architecture near Building" loosely framed around the topic of architectural drawing, featured talks from Kenneth Frampton, Pritzker Prize winner Frank Gehry, Per Olaf Fjeld, Colin St. John Wilson, Mary McLeod and Professor Anderson himself. The spring series, "Mens and Manus" dealing with architectural

modeling, included talks from Robin Evans, Henry Millon, George Ranalli, Andrea Leers, with Berlin architect and teacher Josef Paul Kleihues delivering the Arthur Schein Memorial Lecture.

In the second term this year, the department launched Thresholds a monthly department publication, thanks to the concerted work of student editors Leah McGavern (MArch '94) and Alona Nitzan-Shiftan (SMArchS '93) and designer Neil Harrigan (MArch '93). Each issue is organized around a general theme and features contributions from students, faculty and others at MIT. Articles responding to previous issues are included, making Thresholds a lively and engaging forum for the voices of the Course for Architecture at MIT.

The Special Interest Group in Urban Settlements (SIGUS) continued its Joint Programs initiative in Poland, established in January 1991 at the Kazimeierz Forum in Poland by Politechnika Warszawska, Oxford Polytechnic and MIT. The program offers special linkage opportunities through an annual forum and workshops. In summer 1991 an MIT faculty and student team was sent to Poland to research development processes and the construction industry and to lead a participatory planning approach with a group of tenants in a large housing cooperative in Lublin, Poland. In the spring term, Professor Myer's Level II studio developed proposals for a Center for the Lublin complex. SIGUS also mounted a workshop in November 1991 on the St. Petersburg(Russia) Master Plan Competition. Faculty from Architecture and Urban Studies hosted a group of professionals from Lenigprogor, a major state planning institution in Russia. Architects, planners, economists, activists interested in the momentous changes underway in Europe were welcomed.

Professor Wampler led a design workshop in the spring term in collaboration with students from the University of Puerto Rico on a design for a site in Santurce, Puerto Rico, an area just outside San Juan. The workshop featured site visits for the MIT team, answered by a return visit late in the term by the student/faculty team from UPR.

The Aga Khan Program organized a symposium entitled "Shere-E-Banglanagar: Louis Kahn and Dhaka" at MIT in October. Professor Passanti coordinated the proceedings, which featured papers selected to evaluate the capitol complex both within the context of Kahn's own work and the tradition of Western architectural production in non-Western countries. Visiting Associate Professor Masood Khan, went to Lahore, Pakistan, in March to initiate an Aga Khan parallel Boston/Lahore design studio with the National College of Arts. Professor Porter also participated in parallel studios there and at the Dawood College of Engineering.

Professor Reiter had a one-man show of his drawings and work titled "Images of the City, Real and Imagined" at the Akin Gallery in Boston, and was featured with another artist in a show mounted at the Arthur Roger Gallery in New York. The installation, supported in part by an MIT Humanities Arts and Social Sciences grant, was titled "The City in Five Parts".

The final event of the year was an well attended alumni/ae gathering in the MIT Museum gallery spaces organized in conjunction with the American Institute of Architects convention, held this year in Boston. A symposium, titled "The Audiences of Architectural Journalism", featured MIT alumni editors of architectural journals in informal conversation about the contents and concerns of their respective publications. They were Stephen Kliment (BArch '53), editor of Architectural Record, K. Michael Hays (SMArchS '79, PhD '90) Assemblages, Richard Jay Solomon (BArch '67) Inland Architect, Donlyn Lyndon, Department Head '67-75, Places, and John Dixon (BArch '55), editor of Progressive Architecture.

Awards and honors to Architecture students : Helen Jeffery was invited to be RTKL fellow this summer; Angela Barreda, Susan Hollister and Pamela Sartorelli were proposed for the AIA Foundation Scholarships. Paul Paturzo and Mary Ellen Spampanato were chosen to submit for the Skidmore Owings and Merrill Travelling Fellowship competition.

End of year Institute awards: The Laya and Jerome B. Wiesner Award for achievements in creative arts to Jill B. Soley; Homer A. Perez was given an Albert G. Hill Prize for minority

juniors or senior who have maintained high academic standards or improved the quality of life for minorities.

Department awards: Imran Ahmed and Tao Li were chosen for the SMArchS Award; Alice Dunn received the Sidney B. Karofsky Prize as outstanding student entering the final year of study in the MArch program; Varisara Gerjarusak, Jim May and Polly McKiernan received the Francis Ward Chandler Prize for achievement in architectural design; Eugenie Huang and Susannah (Annie) Kerr shared the William E. Chamberlain Prize. The Alpha Rho Chi Medal, for service to the Department and promise of real professional merit, went to Al Vallecillo. Radziah Mohamad received the American Institute of Architects (AIA) Certificate, and Murat Germen received the AIA Medal for top ranking student graduating from the MArch program this year.

STANFORD ANDERSON

Media Arts and Sciences Section

The Media Arts and Sciences Section, in its fifth year of operation, increased its participation in undergraduate education by offering an additional subject intended for that audience and by expanding its UROP activities and concomitant thesis research and writing activities. As we approach the upcoming review of our academic programs, the Section and the Media Laboratory are exploring more effective couplings of teaching and research programs in newly emerging domains of the media arts and sciences.

EDUCATION:

Graduate:

One hundred and sixty-eight applications for our graduate program were received this year, from which 29 were selected for admission (including eight women) – 18 for the Master's program, and 11 for the Doctoral program. Our graduate student population this year consisted of 82 students (17 women and five underrepresented minorities), of whom 38 were in the Master's program and 44 in the Doctoral program, continuing a long-term shift of balance toward the Doctoral program (compared to 39 S.M. and 37 Ph.D. students last year). Eighteen advanced degrees were awarded during the year (11 S.M. and seven Ph.D.). Forty-seven graduate subjects were offered by the Section this year (an increase of 10 from last year).

Undergraduate:

This year we offered eight undergraduate subjects (up one from last year). While the Section lacks an official undergraduate academic program, the 126 UROP students active in the Media Laboratory over the year have maintained our lively interaction with the undergraduate student body. Of these, many pursue their undergraduate thesis research under our faculty's supervision.

FACULTY AND STAFF:

Tenure:

Associate Professor Tod Machover was appointed a permanent member of the MIT faculty. Prof. Machover's interests include real-time computational interaction through the use of gesture recognition and interfaces that resemble conventional instruments.

New Appointments:

Dr. Aaron Bobick was appointed Assistant Professor of Media Technology in February 1992. Dr. Bobick received the Ph.D. in Cognitive Sciences from MIT in 1987. His interests include human-machine vision, object recognition, categorization theory, cognitive science and artificial intelligence.

This was the second year of a one-year internship as part of a program to widen the entry and preparation opportunities for our academic program, and intended specifically for underrepresented minorities. The second recipient of this internship is Mr. Kevin Brooks, who has been working in the Interactive Cinema Group. Mr. Brooks will begin doctoral studies in the Interactive Cinema Group in September 1992.

Honors & Awards to Faculty Affiliated With the Media Arts & Sciences Section:

Associate Professor Edward Adelson was a co-recipient of the 1992 Rank Prize in Opto-Electronics.

The Provost has announced that Professor Stephen A. Benton has been named the E. Rudge ('48) and Nancy Allen Professor, effective July 1, 1992.

Assistant Professor Rosalind Wright Picard was named the NEC Career Development Professor of Computers and Communication.

Professor Barry Vercoe received the 1992 Computerworld Smithsonian award in Media, Arts, and Entertainment for his work on *Synthetic Performer*.

President Emeritus Professor Jerome B. Wiesner received the 1992 Vannevar Bush Award from the National Science Board, citing him as "humanist-engineer... [who has] helped transform the information and communication sciences by grasping the essential fusion of their technical and social dimensions."

STEPHEN A. BENTON

Department of Urban Studies and Planning

INTRODUCTION

For the Department of Urban Studies and Planning, 1992-93 was a year in which we completed a planning process, reflected on the implementation of the plan and took the first steps in a transition of leadership and focus. We had the benefit of strong reviews from the professional accrediation and visiting process. The report of the teams praised our strengths and noted our continuing leadership in the fields of planning and urban studies.

At the same time, the committee and our own internal assessment called our attention to problems with which we should be concerned: the pressure on students created by rising tuitions and declining financial aid, the urgent need to bring more sponsored research into the Department, and the importance of enhancing the quality of communication and community among faculty members and between faculty and students. These issues are of concern to us. They were among the issues that led us, two years ago, to begin the Long Range Planning Process.

THE DEPARTMENT'S LONG-RANGE PLANNING PROCESS

In this process, we aimed at re-assessing our directions and strategies, guiding the future development of our educational and research programs, and informing the personnel actions we will take over the next decade. The senior faculty as a committee of the whole and various task forces that included other faculty and students with support by Amy Schectman reviewed our mission and overarching values, analyzed ongoing and likely future changes in our principal environments (the urban world, the professions related to planning and their schools, MIT), and drew from these studies implications for our policies and programs.

The context for our teaching, research and practice has shifted considerably since the department took its current form in the early seventies. We now believe the time has come to seek greater coherence in our efforts and to adjust our work to reflect the changes that are on the horizon.

We agreed to refocus the department over the next decade, building upon our current strengths, reflecting the values and issues we believe are important, and responding to the changed environment in which we must work. Our new mission statement includes:

o Focusing the department on development, by which we mean the process of planning and carrying out programs of change, guided by an idea of what constitutes progress.

o Specializing in three aspects of development -- the development of the built environment, economic and social development of communities and regions, and the condition of the natural environment as it is impacted by development.

o Reinforcing our identity as a center of education and research for improving the quality and effectiveness of professional practice.

o Embracing more actively than in the past the technological possibilities of our presence at MIT, especially information technology.

o Expanding our efforts in undergraduate education by emphasizing teaching that is of value to a broad cross-section of MIT undergraduates, while continuing to promote and refine our undergraduate major.

o Educating practice-oriented students as leaders of development programs in public, private and non-profit sectors, and preparing them to take action to promote social and economic reform, improve the quality of places, and improve economic prospects for those at the bottom of the economic ladder.

o Educating research-oriented students to advance basic knowledge of community development processes and issues.

o Maintaining our commitment to work in both developed and less developed countries, and encouraging comparative work which identifies the linkages between the two, their differences and similarities.

o Bringing academic resources to bear on the problems confronting planners, developers, citizens, and public decision makers. For this purpose, organizing research groups in each of the areas of central concern to us, and orienting our doctoral students to the work of these groups.

o Improving and extending the impact of the profession's concerned with the three aspects of development named above. To this end, providing continuing intelligence about conditions and changes in the functioning of regions, cities, and communities. Strengthening our current programs for the continuing education of mid-career professionals in these fields.

IMPLEMENTATION

Carrying out this mission will require changes in our priorities, new resources and altered ways of conducting our work. In particular, in the future we will need to:

o Maintain a clear sense of priorities in replacing faculty who retire or leave over the next decade, to reinforce the work of research groups and provide the essential crosscutting perspectives.

o Expand the resources available for student aid, and tailor our admissions more closely to faculty strengths, interests and financial resources.

o Expand sponsored research, and adjust the incentives for faculty and research groups to encourage MIT-based work.

o Create new links, and expand and reinforce existing relationships with faculty in other schools, departments and centers at MIT.

o Organize events which put students and faculty in contact with each other, and connect us with alumni and the practice and research environments.

o Consolidate and improve our space so that research clusters each have home bases, the departmental headquarters is central to activities, and informal contact across all areas of the department is maximized.

o Mount a development effort emphasizing research endowments, funding for student aid, and special activities and events.

o Develop and maintain internal administrative and budgeting systems -- Institute links that support the implementation of this plan.

While 1992-93 marks the official beginning of implementation of the plan, the Spring of 1992 saw the initiation of some efforts to meet the challenge presented by our mission statement. For example, Professor Clay chaired a committee to review theallocation of departmental financial aid resources. The committee considered the possibility that a different distribution might get more funds to those most in need and yield a higher fraction of top ranked admitted students.

Under a new plan proposed by the committee and approved by the faculty, existing resources were re-targeted with the result that students awarded aid for 1992-93 will get more aid and because of the success of the intern program and external resources, this comes without a dramatic reduction in the number of needy students who are assisted. We also experienced a higher yield of top ranked students in the recent admissions round, including the yield of minority students who in the previous years increasingly opted for schools that provided more assistance than we offered. While further evaluation of the new system is in order, some improvement is certain. Attention now turns to generating additional resources and to providing greater support, including support for Ph.D. students beyond their second year.

Another effort we took towards implementation was enhancement of our Undergraduate Program. We begun curriculum development work on several of the eight courses that we plan as the core of a revived undergraduate program. This will led to sharped specializations and two minors to be presented to the Committee on Curriculum in the Fall. We are especially pleased to have become the home of the new Minor in Education which grew out of MIT's K-12 Initiative. As part of an interdisciplinary effort, we will prepare MIT students to teach math and science in elementary and secondary schools. Besides being the home of the program, we will mount offerings to help students understand the organizational and social context of urban education.

Pursuant to the plan, we also started to review our curriculum planning, faculty responsibility, and administrative/budgeting processes with the goal of creating mechanisms by which the plan can be implemented effectively. Mechanisms have been put in place for 1992-3 to implement the plan and to make all aspects of the administration of the department match the mission agreed to by the faculty. The entire planning process and the initial steps were made in conjunction with Professor Phillip Clay who became Department Head on July, 1, 1992.

EDUCATIONAL PROGRAMS

Our Ph.D. and MCP programs are among the strongest in the country. Applications were up by 20 percent last year reflecting a continuing ability on our part to attract highly qualified students even in competition with our lower-cost competitors in the large state universities. While this sharp increase is somewhat of an aberration we are able to proceed with our planning from a position of strength.

Our pioneering programs in developing countries and in environment planning and negotiation, have continued to attract large numbers of students and have

maintained their high levels of quality. Our programs in housing and environmental design have benefitted from a much closer collaboration with the Center for Real Estate Development. Planning support systems and research in Geographic Information Systems, (GIS) under the direction of Professor Joseph Ferreira and Associate Professor Lyna Wiggins, have achieved increase prominence in the Department both as reflected in its research base and in the number of students engaged in coursework, UROP's and thesis research. Several other faculty, including Professors Karen Polenske and Ralph Gakenheimer have redirected courses to take advantage of computer technologies.

In the coming year, we will continue our efforts to improve our Ph.D. and MCP Programs in the light of the directions set out in our Long Range Plan. The Ph.D. Committee will continue the work of adapting our doctoral program to the research agenda of our five research groups.

The Ph.D. task force calls also for a series of core courses for the first field to strengthen both the planning theory and methods offerings. A task force on the MCP Degree urged further articulation of specializations and the practice competencies for which we want to educate our students.

In 1991-2, we developed a new Internship Program under the leadership of Amy Schectman. The program has been a success beyond our wildest expectations. Agencies were quite excited about getting our students and student response has been extremely positive. Over the year, more than 40 students participated. More then 60 agencies and firms offered positions.

The success of the program and the subject on "Professional Identity" have inspired us to give more careful attention to a host of MCP program features relating to professional education. Some of this learning will be incorporated in the 1992-3 programs and courses while other aspects await further development.

The Community Fellows Program under the direction of Adjunct Professor Melvin King had a very successful year, hosting more than a dozen mid-career professionals whose work has focussed on youth programs in cities around the country. New three year support was awarded from the Ford and Kellogg Foundations.

The Special Program for Urban Regional Studies (SPURS), under the direction of Professor Karen Polenske, continued to support mid-career professional fellows from around the world. The program spent part of the year preparing for its 25th Anniversary in October 1992 when President Oscar Arias will be the guest speaker and more than 200 former fellows, faculty and sponsor will visit the campus. The program also has begun to consider a strategy for raising endowment funds.

EVENTS

In the 1992-3, the Department sponsored several colloquia, each of which drew an audience of 30 to 40 faculty and students. Some of these were devoted to questions related to long range planning. Others dealt with intellectual questions underlying issues in planning, development and pedagogy.

The Department's Professional Development Institute, under the direction of Amy Schectman, was held for the third time in January, cosponsored by the

Center for Real Estate and the Tufts Planning Program. Twenty-one workshops in skills of communications, writing, management, and GIS Systems, among others, were offered to approximately 325 Boston area professionals, most of whom were alumni/ae or Master's students in DUSP, CRE, or Tufts. Alumni/ae attendance was strong and student participation was substantially higher than in 1990-1, as the reputation of the Institute has grown.

Several other events marked the year. Professor Richard Schramm put together a distinguished team of professionals in the area of Economic Development. In two meetings here, they offered a number of helpful ideas about teaching and research. We hope to expand and further utilize this venue in the coming year and to expand the seminar series to bring field research to our students.

Professor Bernard Frieden and his colleagues in the Sloan School held a seminar in economic development aspects of universities. Members of the faculty collaborated in a well-received conference entitled "Un-Gendering the Environment." Professor Lawrence Susskind again led the Salzberg Seminar while Professor Mark Schuster directed the Mayor's Institute for Urban Design. Professor Emeritus Lloyd Rodwin put together what promises to be an impressive seminar in honor of Albert Hirschman. Several members of the department participated and took leadership in the first international conference of the Association of Collegiate Schools of Planning, in England. Others attended the recent Rio Conference on the Environment.

Faculty/student studios and the study groups convened in China and Japan. Other groups spent time and developed projects in Eastern Europe and the former Soviet Union. Proposals are pending for major design and development projects that will expand and extend these international efforts.

FACULTY

One of the issues of central concern to us is the mix of faculty in DUSP. We seek to increase the number of minorities and women on the faculty, to strengthen our junior faculty in the light of the increasing ratio of tenured to total faculty, and to achieve a balance of faculty members who devote themselves, respectively, mainly to scholarship or mainly to practice-oriented research.

The plan compels us to take care that in a period of no growth to use vacancies to further the plan goals, the year saw mixed results. A national search produced Professor Frank Levy to fill a vacancy left by Bennett Harrison. Professor Elijah Anderson is our choice to succeed Professor Frank Jones who retired February, 1992. The real estate position is still open. Professor Edwin Melendez is leaving to take a position as Professor and Head of a center at the University of Massachusetts. Finally, Professor Donald Schon stepped down as Department Head and took early retirement. He will become a Senior Lecturer and assist research groups in assembling new projects. He will continue to work on his Ford funded project program related investment.

Several faculty research projects are noteworthy. Professor Karen Polenske did environmental modelling for Los Angeles. Professor Gary Marx received support from NSF to research the impact of technology on privacy. Professor Phillip Clay received additional support for his evaluation of a youth demonstration project. Professor Langley Keyes published an important book

on community development (Strategies and Saints). Professor Larry Vale's book on architecture and political power (Architecuture, Power and National Identity) breaks new ground and Professor Donald Schon's book (The Reflective Turn) represents an important contribution to the study of organizations. At least a half dozen new books are in their final stages. Professors Joseph Ferreira and Lyna Wiggins have continued to build the computer lab's leadership in application of GIS.

PHILLIP L. CLAY

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; annually received current funding also supports teaching and student financial aid, in addition to publications, documentation, student travel, and outreach activities. The central office, located at MIT, serves as a continuous liaison for activities carried out at both universities; coordinates joint, program-wide activities; maintains a steady exchange of fiscal and substantive information between the program and the donor; and coordinates program outreach in the Muslim World.

During the 1991–92 academic year, the central office continued its communications and outreach work for the program. Internal communication between and among students, faculty, staff, and the Harvard and MIT communities functioned through the AKP monthly internal calendar and announcement listings that together alerted the community of program activities and resources, staff travel, program meetings, and special events. The central office also compiled and distributed periodic listings of grant and scholarship opportunities pertaining to the interests of AKP students. Two issues of the fourth volume of a program-wide newsletter, which reports on the program's many activities, were produced and distributed to the AKP community, interested scholars, professionals, and institutions at home and abroad. The "Evening With" series, five lectures and discussions concentrating on the creative formation of modern artists and authors influenced by the fusion of Eastern and Western cultures, was coordinated by Professor Nasser Rabbat. A two-part AKP study group was offered to students and local professionals by the distinguished Iraqi architect and writer Rifat Chadirji, winner of the 1986 Aga Khan Chairman's Award. As part of the AKP's Parallel Centers program of international outreach, graduate studies enrichment and development continued at both the University of Jordan in Amman and the Dawood College of Engineering and Technology, Karachi, Pakistan.

Two new publications were released. *Muqarnas 8* is the eighth edition of the program-sponsored annual that represents new work in the field of Islamic art and architecture; *Monumental Inscriptions from Early Iran and Transoxiana* by Sheila S. Blair is a publication of the 78 earliest extant inscriptions surviving on architecture in Iran and Transoxiana from the first five centuries of Islam.

FACULTY

The Aga Khan Program Committee, charged with policy decisions during the 1991-94 cycle, included: Stanford Anderson, head, Department of Architecture, MIT (chair); Barbro Ek, director, Aga Khan Program (ex officio); John de Monchaux, dean, School of Architecture and Planning, MIT ; William A. Graham, director, Center for Middle Eastern Studies, Harvard; Philip S. Khoury, dean, School of Humanities and Social Sciences, MIT; Brendan A. Maher, dean, Graduate School of Arts and Sciences, Harvard; Gerald M. McCue, dean, Graduate School of Design, Harvard; Gülru Necipoglu, John L. Loeb Associate Professor of the Humanities, Harvard; William L. Porter, acting director, Design for Islamic Societies unit of the Department of Architecture, MIT; John Shearman, chair, Department of Fine Arts, Harvard.

Leventhal Professor of Architecture and Planning William L. Porter assumed responsibilities as acting director of the Design for Islamic Societies (DIS) unit after Aga Khan Professor Ronald B. Lewcock left to join the faculty at Georgia Institute of Technology's Department of Architecture. Professor Lewcock returned to the DIS periodically to serve as a visiting professor. Other full-time AKP faculty included Visiting Associate Professor Masood Khan and Aga Khan Assistant Professor of the History of Islamic Architecture, History, Theory and Criticism Program, Nasser Rabbat. Visiting Aga Khan Professor Klaus Herdeg, chairman of the architecture division at Columbia University, joined the DIS faculty for the fall semester.

ACADEMIC PROGRAMS AT MIT

The Design for Islamic Societies (DIS) component of the SMArchS program

This year, six new students were enrolled in the DIS component of the Master of Science in Architecture Studies (SMArchS) degree program. With six outgoing students, the unit accommodated 12 SMArchS students and one PhD student, Akhtar Badshah. One of the graduates of the 1992 SMArchS degree, student Tao Li from the People's Republic of China, was co-recipient of the "Best Thesis" award from the Department of Architecture. The faculty consisted of Professors Porter, Khan, Lewcock, Herdeg, Arizona architect Jody Gibbs who taught a practical construction workshop during the Independent Activities Period (IAP), and other scholars and architects who participated as visiting lecturers.

Student reflection and debate focused on both practical and theoretical issues concerning the architecture characteristic of nonwestern societies. Students were encouraged to compare traditional, Islamic architectural forms and structures with those developed after the spread and application of Western ideas in modern times. The unit considered appropriate responses to

climate, building materials, and building technology as well as the socio-cultural attitudes and values that directly relate inhabitants to their environment.

In the fall of 1991, first-year students participated in two workshops that together formed the introductory course "Architectural and Urban Contexts in Islamic Societies," a course dealing with a number of major issues vital to architectural and urban development in Islamic societies as well as in other cultural regions in the developing world. On this occasion, students explored the principles upon which a formal relationship can be established between extraordinary architectural and urban configurations of the past and new designs that will accommodate demands of today and tomorrow. Staff and students worked closely together throughout the series, but also independently for short periods to explore particular issues.

The first workshop familiarized students with Islamic as well as other Asian and African urban and social organization. It further considered the relationship between the urban structure of traditional societies and that of cities or parts of cities that have developed under Western influence. The first workshop focused on the Iranian city of Kashan, a city still rooted in pre-20th century architectural technology, commerce and life style. Recently it has been subjected to powerful 20th century pressures that are affecting the old physical fabric and eroding the values and traditions of the inhabitants. The second workshop dealt with a site close to the center of Beirut, Lebanon, and next to a planned public park that is speculated to be the next territory for residential growth. It provided an opportunity to address the single-minded direction that the architecture of modern residential Beirut has tended to take and offer alternative solutions.

In addition to the design workshops, DIS offered two other courses in the fall of 1991. "Approaches to the Study of the Architecture and Urbanism of Islamic Societies," taught by Professor Khan, consisted of lectures on theory, criticism, and architectural design in the Islamic world and had three aspects. The first aspect considered methodological questions followed by an overview of the development of Islamic architecture from the 7th to the 18th centuries. The second dealt with issues surrounding the cultural disjunctures experienced by Islamic and other third world cultures. The third aspect studied contemporary practices in Islamic societies by examining the various stages of architectural theory and development through the colonial and post-colonial periods. "Methods of Inquiry in Architecture Studies," taught by Professor Porter, examined the nature of architectural inquiry, principally the sort that enables architectural response to contemporary problems that are particularly challenging or that fall outside the scope of conventional practice.

The spring term was devoted to a studio workshop, "Design Responses in the Event-Bound Place: Historic Urban Edges in Boston and Lahore," taught by Professors Porter, Khan, and Mr. Timothy Johnson. Specific sites in Boston and Lahore, Pakistan, that share similar design issues and historic circumstances were considered. In both places, powerful economic and functional forces, as well as the technological culture that supports them, are seen in conflict with cultural continuity and societal needs for identity. The problem assigned in Boston dealt with taking the central artery underground and in Lahore with the renewed relationship of the old citadel with the old walled city. A parallel but identical studio was offered at the National College of Arts (NCA) in Lahore with participation of students from the NCA and the AKP parallel center at Dawood College of Engineering and Technology (DCET), Karachi. The final part of the studio was held at the NCA and included students and faculty from MIT as well as the two Pakistani institutions. As part of the outreach activities, professors Maqsood Pasha of NCA and Muhammad Asif Nawaz of DCET visited the DIS for three weeks to assist with the studio, while Professors Porter, Khan and Mr. Johnson taught various stages of the studio in Lahore. The studio concluded in Lahore with a 10-day workshop in which the students from MIT and from Lahore worked together to modify and deepen their proposals. The workshop concluded with an all-day review involving several local professionals and teachers and with a dinner attended by the governor of the Province who participated in honoring the students who completed the workshop.

While in Lahore, Professor Porter delivered relevant talks to the faculty, students, and the profession. He also stopped in Amman, Jordan, to give the first lecture in a new Aga Khan Lecture series there, designed to give prominence to their new Aga Khan unit. In both Lahore and Amman, Porter continued discussions of how each "Parallel Center" might develop over the next few years.

History, Theory and Criticism Program (HTC)

In the fall of 1991, Professor Nasser Rabbat, winner of the 1991 Malcolm Kerr Dissertation Award in the Humanities awarded by the Middle East Studies Association of North America, taught "City Form in the Mamluk Period" and "Palaces, Houses, and Caravanserais: Non-religious Architecture in Islamic Lands." The former delved into the dynamics of city form of several cities of the central part of the Islamic world, the Levant and Egypt, during late-classical to pre-modern times. The latter course was a typologically-limited survey of Islamic architecture dealing with residential, commercial, military, and monumental architecture from the seventh to the twentieth centuries.

"The Mother of the World: An Architectural History of Cairo" and "Meaning in Islamic Architecture" were the two courses taught by Professor Rabbat in the spring. The course on the history of Cairo's architecture had two goals: to understand the development of the city, urbanistically and architecturally, in relation to its site, ecology, history, and culture; to examine the major types of building in Islamic architecture through the Cairene examples and through comparisons with

developments elsewhere in the Islamic world. The seminar on meaning in Islamic architecture explored the expressive intent of numerous selected Islamic monuments including the Dome of the Rock, the surface articulation in Umayyad palaces, the round plan of the city of Baghdad, and the meaning of the Iwan. Professor Rabbat also offered a three-day IAP course that involved students in short design exercises based on visualizations and representations of architecture of the past. The course was open to the MIT community.

The Aga Khan component of the History, Theory and Criticism Program awarded Kara Hill a PhD degree in the fall of 1991. In the spring of 1992, Imran Ahmed secured a three-year leave of absence from the Department of Architecture; he was granted an SMArchS degree and was a co-recipient of the Department's "Best Thesis" award. Of the four AKP doctoral students in the HTC program, Imran Ahmed and Shirine Hamadeh were in residence in Cambridge; Iffet Orbay was in residence in Quebec, writing her dissertation; and Richard Brotherton continued work on his dissertation while based in New York.

VISITING SCHOLARS

During 1991–92, the AKP hosted three visiting scholars. Tarek Fadaak, chairman of the Department of Urban and Regional Planning at the College of Engineering, King Abdul Aziz University, Jeddah, Saudi Arabia, continued his research on low-income housing policy guidelines for Saudi Arabia with the Aga Khan Unit for Housing and Urbanization at Harvard University. Hafez Chehab, assistant professor and coordinator of the art history program at the State University of New York, College at Brockport, prepared for the publication of a monograph on the architectural decoration of 'Ayn al Jarr and an archaeological survey based on his studies of the antiquities of Lebanon performed from 1980 to 1983. The program's most recent visiting scholar, Gautam Bhatia from New Delhi, is researching vernacular mud architecture. In India, Mr. Bhatia is the senior partner of The Architecture Alliance, member of the panel of architects for the Housing and Urban Development Corporation, and chairman of the Laurie Baker Building Center.

STUDENT SUPPORT

Tuition and living expenses for three doctoral and 11 SMArchS students at MIT were funded in whole or in part. Eight students from MIT and three from Harvard were awarded summer travel grants for research in Spain, Greece, Germany, China, Morocco, Egypt, India, Macao, Iran, and Portugal. An additional eight MIT students, one Harvard student, and three students from the AKP Parallel Centers in Pakistan and Jordan were awarded travel funds to participate in internship and student field research programs in Pakistan, Jordan, and Spain.

LIBRARY AND INFORMATION RESOURCES

Specialized acquisitions and services at the Rotch Architecture Library continued to be provided through endowed funds. The AKP's videodisc system located in the Rotch Visual Collections, *Images of Islamic Architecture*, was upgraded significantly, therefore increasing its use. In addition to 27 formal demonstrations, the system was consulted weekly by patrons trained and directed by AKP Archivist Kim Lyon. Ms. Lyon organized and completed "Visual Archives Acquisitions 1980 to 1990," a ten-year compilation of the archives' 35mm slide collection, which provides access to images by country, city, photographer, and year and is consulted frequently by staff, students, faculty, and visiting scholars. She also edited and added a total of 3,000 slides to the AKP Visual Archives' 100,000 slides. These slides were the result of nine Travel Grants awarded by the Program to Harvard and MIT graduate students in 1991.

The AKP book collection at the Rotch Library has become a well-known and valuable source for many. Besides regularly serving students and faculty, Omar Khalidi, reference librarian for the AKP at the Rotch Library, assisted such diverse groups as architectural firms rebuilding Kuwait, the Department of Defense, and a professor of architecture from Beirut who found at the Rotch Library books on architecture published in Lebanon but no longer available there.

SEMINARS

In October of 1991, the AKP organized "Sher-e-Banglanagar: Louis Kahn and Dhaka," a two day symposium that focused on Louis Kahn's Capitol Complex in Dhaka. The symposium presented a variety of speakers whose themes ranged from general issues of architectural form and symbol to the political and technical implications of Western architects practicing in developing countries.

BARBRO M. EK AND WILLIAM L. PORTER

Center for Advanced Visual Studies

Through projects, research and teaching the Center for Advanced Visual Studies has continued its efforts in art-science-technology and environmental art and performance.

In its 25-year history (CAVS was formed in 1967) the Center has hosted 185 Fellows - mostly artists - and 75 graduate students have received a Master's degree in its MSVisual Studies/Environmental Art and Performance Program. CAVS has hosted and participated in many international conferences, exhibitions and artistic projects. Because CAVS is the first academic institution dedicated to art-science-technology, many planners and founders of new centers and programs have sought advice at CAVS in recent years towards new developments internationally and nationally. Following ARTTRANSITION '90 the CAVS 25th anniversary celebration in June, 1993, will bring together artists, planners and directors of new institutions to exchange their views on the future of art, environment and education and art & technology specifically. The explosive growth of the field has drawn ever-increasing numbers of academic and creative activists together in the development of new media and programs. However, during the 1991/92 academic year the emphasis in CAVS work has been on individual articulation of artistic/environmental tasks in a national and international context.

CAVS director, Prof. Otto Piene created, with Zeidler Roberts Partnership, architects of Toronto, Canada, the public section of MediaPark in Cologne, Germany. Its centerpiece, "STARPIT", is a large fountain/amphitheater for leisure and performance. Part of the opening celebration was an O.P. sky event in the Media Park using his 150-foot-long large inflatable sculpture, "Milwaukee Anemone". The same sculpture/event was featured at the opening of "UNDR", an international exhibition on light and new media at Charlottenborg, Copenhagen, Denmark in the spring of 1992; among other participants: former CAVS Fellows, Dale Eldred and Thorbjörn Lausten. Throughout the year Otto Piene has also worked towards his environmental/architectural installation for the new German National Assembly (Bundestag) building in Bonn, Germany - "80,000,000".

CAVS Fellow Paul Earls continued his work on a central laser art ambiente - "Laser Atrium" - for Liberty Science Center off Manhattan/New York. He will contribute a richly programmed laser/sound environment to a Cologne, Germany, metro station currently being built (in collaboration with KHM - Kunsthochschule für Medien - Cologne)

CAVS founder, Gyorgy Kepes' work, has been given a new place of continuing recognition and acclaim at the Gyorgy Kepes Museum and Art Center in Eger, Hungary. Located in Kepes' home country, the "Kepes Memorial" collects, curates and displays important art work and documents of his entire life's effort in art and education and it gives testimony to his seminal role in art-science-technology. The Düsseldorf, Germany, Kunstmuseum has installed "Lightspace" for permanent display - the reassembled Group Zero room of documenta 4, Kassel, 1964, where Otto Piene, Heinz Mack and Günther Uecker created kinetic light/space works in a closely integrated effort.

Former CAVS Fellow, avant garde art performer Charlotte Moorman who died in November, 1991, was given a festive and artistically rich memorial at the Whitney Museum of American Art in New York City. CAVS Fellow Ellen Sebring won a grant from the American Film Institute, Los Angeles, CA, to participate in the Directing Workshop for Women in Hollywood in 1992. Elizabeth Goldring

(videographer, Ellen Sebring) created a videotape, "A Visual Language for the Blind", based on a collaborative performance and project between Robert Webb, Senior Scientist at the Eye Research Institute, Boston, MA, and herself and a number of CAVS artists. Her ongoing work addresses low-bandwidth communication (together with Robert Webb and Prof. Aaron Bobick, MIT Media Lab, also with Eli Peli of the Eye Research Institute). Besides several outdoor poetry/sculpture installations Panos Kouros had a one-man-exhibition, "Now Blueing", at the Boston Kimball Bourgeault Gallery. Nathan Hemenway also had a one-man show, "Carousel", at the Boston Mobius Gallery. Several CAVS artists - Paul Earls, John Powell among them - contributed to First Night Boston, 1991.

Former ("founding") Fellow, Wen Ying Tsai, won the Grand Prize of the Second Biennale for Art and Technology in Nagoya, Japan and former Fellow and MSVisS graduate, Bill Seaman, won the "interactive media" prize at the Linz, Austria ARS ELECTRONICA, 1992. Artist Fellow Joan Brigham - together with Fellow Christopher Janney - installed their collaborative environmental work, "Hopscotch", at the National Museum of American Art/Smithsonian Institution in Washington, DC. Fellow Tal Streeter has been commissioned to create a large-scale environmental sculpture at the art academy in Seoul, Korea.

Otto Piene participated in several international group exhibitions, notably "Schwerelos" at the Belinische Galerie, Schloss Charlottenburg, Berlin, Germany, and the "Gruppe Zero" retrospective at Galerie Neher, Essen, Germany (authoritative catalog). He had one-man shows at Galerie Löhrl, Mönchengladbach - "SKY ART" and "SKY ART" catalog - and Galerie Lauter, Mannheim, Germany, and at Gallery 360°, Tokyo, Japan. Gyorgy Kepes showed his work in solo exhibitions at Alpha Gallery, Boston, MA and at the Provincetown Art Association and Museum, Provincetown, MA.

With O.P. on teaching sabbatical leave, classes at CAVS were conducted by Paul Earls (Advanced Visual Design, 4.382) and Elizabeth Goldring (Art and the Environment - Imagery East/West, 4.372 - with Tal Streeter). A good number of UROP students are being advised by both Dr. Earls and Ms. Goldring. Master of Science in Visual Studies degrees were given to Gregory Haun (The Timely Self-Portrait Machine); Caryn Johnson (Unfoldings); Daniel Spikol (Digital Diorama); Diane Willow (Gardening the Elements in a Landscape of Technology).

Symposium presentations and lectures were given by most CAVS artists in places such as the Nagoya, Japan, Museum; the Taipei, Taiwan, National Institute of the Arts; the Berlin, Germany, Hochschule der Künste; the Helsinki, Finland, University of Industrial Arts; the Cologne, Germany, Kunsthochschule für Medien; the Gyewon School of Art in Seoul, Korea; the Eye Research Institute of Boston, MA.

A major monograph, "Gruppe Zero" has been published by Propyläen Verlag, Berlin, Germany. O.P. contributed to "Digitaler Schein" (Philosophical Aesthetics of art-and-technology) published by Suhrkamp, Frankfurt, Germany. O.P. wrote "Art-and-Technology: Recent Efforts in Materials and Media" for MRS Bulletin XVII,1, and "Issues in Art and Technology" for Sculpture, June 1991. The paperback version of Todd Siler's "Breaking the Mind Barrier" was published by Simon & Schuster in spring, 1992.

OTTO PIENE

Center for Real Estate

The Center for Real Estate (CRE), founded in 1984, carries out research and teaching programs in the field of real estate development, investment, and management. The Center's principal activities include an 11-month mid-career professional degree program leading to a Master of Science in Real Estate Development and a research agenda of issues relating to the planning, development, and management of real estate, including its financial performance.

The Center has this year widened its international involvements to include the Pacific Rim more explicitly. Mr. Ronnie Chan, Chairman of three large publicly-traded real estate companies in Hong Kong, joined Center Chairman Thomas Steele as co-chair of the Center's Advisory Committee. Mr. Chan has promoted the Center's interests vigorously, resulting in an increase in member firms from Hong Kong. These new contacts should lead to increased numbers of applicants to the masters degree program and possible research and curriculum development opportunities in the future. A seminar by Center faculty is planned for the fall of 1992 to be held both in Hong Kong and in Singapore to help the Center develop more of a presence in a part of the world where there is a strong interest in global real estate development and investment.

The Center continued to strengthen ties with the University of Amsterdam, hosting a seminar in June for its graduate students who were travelling in the U.S. Faculty associated with CRE also taught seminars on land valuation and the privatization of housing markets in Eastern Europe. Lecturer Marc Louargand gave a course on property valuation and urban economics to Polish municipal officials in Cracow. Center Director, Professor Lawrence Bacow took part in a seminar in Moscow describing how a private market economy organizes itself to produce housing. This was a continuation of earlier work also sponsored by the U.N. Human Settlements program. Professor Bacow also took part in a joint MIT-Japanese workshop and conference on preserving housing in urban centers. A follow-up workshop is planned to take place in Tokyo next fall.

Another significant new undertaking for the Center was the development, in partnership with the Massachusetts Housing Finance Agency, of an executive program for minority property managers. The program is designed to enable participants to expand their businesses by enhancing specific financial and managerial skills. The week-long pilot program will run in July, 1992. Lecturer Sandra Lambert is the coordinator of this, CRE's second short program for minority executives.

EDUCATION

The seventh class of 28 CRE graduates received their MS degrees in Real Estate Development in October, 1991. Four joint degree candidates, officially members of the CRE Class of 1992, completed all requirements for both degrees and graduated in June. The incoming class, the 35 members of the Class of 1993 plus four joint degree candidates, were selected in March. Again this year there was a rise in the number of international applicants. The new class has 11 students from outside the U.S.

Course requirements for the degree were revised to reduce the number of core courses required from eight to seven in order to give students more flexibility in taking courses in other parts of the Institute. Design for Urban Development is now optional though recommended.

The curriculum in many courses was revised to reflect the industry's change in focus away from development. Managing the Development Effort became Managing the Real Estate Company and focused on issues that concern firms at this stage in the business cycle: downsizing, developing new lines of business, using information technology. The renamed Site and Development Prototypes dropped the studio portion to become a lecture course now taught by Professor Gary Hack along with Lecturer Albert Lamb. Public/private partnership became a more important element, particularly in the Construction Technology and Building Development course co-taught in 1991 by Senior Lecturer James Becker, representing private industry, and Lecturer John Carlson for the public sector.

RESEARCH

The research of the Center this year concerned the behavior of real estate products over the business cycle. Professor William Wheaton and a colleague used a new source of leasing data to create a set of office market rent indices. Examination of these showed that vacancy ultimately determines rent levels, not continual rent changes. The data had not been available previously to test this hypothesis. Professor Wheaton also surveyed the current state of various product markets and concluded that the possibility of a rebound in these markets will be due to a continued severe credit crunch rather than a strong surge in demand. Work by PhD graduate Jun Han on real estate investment trusts (REITs) found that return characteristics are comparable to the returns on commercial real estate and long-term bonds. Lecturer Marc Louargand found that relatively few pension funds are willing to devote a significant part of their portfolios to multi-family housing, finding it too small, management intensive and risky to justify the low yields. The Center also published two working papers on the timing of development decisions by Visiting Professor Dennis Capozza.

PROFESSIONAL EDUCATION

The Center's professional education program included the fourth session of the Minority Developers' Executive Program This year the MDEP celebrated a milestone by "graduating" its one-hundredth participant. Participants came from many U.S. cities, including a sizable group from Los Angeles with the encouragement of Mayor Bradley. Support for the program continues from CRE faculty who teach pro bono, and from the Bank of Boston and the City of Boston. The third Pension Real Estate Association (PREA) Institute focussed this year on asset management. It was taught by a number of CRE faculty and practitioners and enrolled 45 pension fund sponsors and advisors.

The seventh summer of short professional development courses brought almost 150 real estate professionals to MIT from throughout the U.S., with a few from abroad. Offerings included three courses given in previous years which continued to attract good attendance in spite of the battered state of the industry. A new course on Management Information Systems attracted more interest than was anticipated especially from middle- and upper-level managers.

MEMBERSHIP

Income from membership rose, as the Center closed the year with 68 supporting members including 12 members who joined in 1992. Five of the new members are development and investment firms from Hong Kong. Others are mainly large real estate investment or consulting firms, about half of which are based in New England. Members continue to support the Center in non-financial ways through providing case study sites, lecturing in classes, taking part in the Rose Lunchbox series, and supporting student research.

Semiannual members meetings were held in December and June. The topic for the winter meeting was Real Estate in the Year 2000. Professor Lester Thurow spoke at the evening session on "Prospects for the Economy Over the Next Decade." He was followed the next morning by three MIT professors and a demographer from the Rand Corporation who covered projections for population changes, urban design, financial markets, and the structure of the real estate industry. The June meeting, "The New Banking," focussed on the future of the banking industry and the resulting impact on real estate. The evening program featured banking industry speakers with different perspectives on possible futures. The morning discussion included presentations by a banker, an ex-Treasury official, and Ford International Professor Emeritus, Charles Kindleberger giving an historical perspective of the banking industry.

ADMINISTRATION

In recognition of the breadth of real estate activities the Center is involved with, 'Development' has been dropped from the Center's name, though not from the degree, which remains a Master of Science in Real Estate Development. Recent personnel changes have brought alumna Patricia Brady, Class of 1988, back to MIT as Associate Director with overall responsibility for non-academic operations at the Center. She replaced Mary Lou Boutwell who returned to the private sector. Another significant planned change will bring Professor William Wheaton to the Center as Director starting in September of 1992. Current Director, Professor Lawrence Bacow, will return to full-time teaching and research.

LAWRENCE S. BACOW

Media Laboratory

INTRODUCTION

The worldwide corporate acquisitions, mergers, and joint ventures during 1991–92 are living proof of the 1981–82 theories behind the founding of the Media Laboratory (Media Lab). Channel and content, that which processes and that which is processed, are no longer independent, but woven into a new opportunity for education, entertainment, and business. The Media Lab and its predecessor groups are certainly the birthplace of multimedia computing, which is now a new industry.

Digital television is a current example of a pure engineering approach that is not sufficient. The intellectual challenge is not picture resolution, error correction, or bandwidth conservation, but new content opportunities.

The Media Lab has been very active this academic year on the international landscape of television. A world tendency toward reckless nationalism is pushing for three incompatible systems and placing protectionism in front of consumer good. The Lab has been active in working with Japan to redirect their course and has successfully prompted changes toward digital technology in the European Community. We find ourselves in small conflict with the Federal Communication Commission because current submissions are overwhelmingly directed at high definition, the least important variable in television. Nonetheless, the FCC appears to be adopting notions of scalability and extensibility, originally conceived and implemented at the Media Lab.

In parallel with such idea transfer, the Lab has made several important breakthroughs this academic year. Examples include:

- real-time, full-color, shaded-surface, synthetic holography that is the size of a tea cup
- face recognition on a modest workstation that can find a likeness from 8,000 candidate images in less than a second
- massively high-resolution printing of very low-resolution images taken over time
- a new acoustic processing technique for music authentication and room sound simulation
- video data compression almost two orders of magnitude greater than previously achieved

These and other achievements are reported in the Media Lab's new monthly publication for sponsors, FRAMES, edited by Christopher Gant and designed by Betsy Cimento. FRAMES is purposely glossy and highly illustrated, and consequently widely read. Its circulation of almost 1,000 includes many people who hang it on their walls as art.

SPONSORS

Research Sponsors

The Media Lab's research volume grew substantially from $7.4 million in FY 1991 to $8.6 million in FY 1992 — a growth rate of 16%.

Sponsorship also grew in several dimensions during FY 1992. One of the Lab's major research consortiums — "Movies of the Future," directed by Media Lab Associate Director Andrew Lippman — expanded its membership to include Bellcore and Intel. Bellcore, in addition to this consortium membership, also began sponsoring a project in "Multimedia Magazines" directed by Professor Glorianna Davenport. News Electronic Data (NED) has funded a new project on "Interface Agents" directed by Professor Patricia Maes.

In December 1991, British Telecommunications signed a major, five-year, $2.6 million contract between BT Laboratories and the Media Lab to support a program "Advanced Image Tools for Telecommunication." This program, directed by Professor Alex P. Pentland, supports research in "Annotation Tools for Digital Video" by Professors Glorianna Davenport and Kenneth B. Haase, "Tools for Finding 'Things'" by Professors Alex P. Pentland and Aaron F. Bobick, and "Tools for Finding 'Stuff'" by Professors Edward H. Adelson and Rosalind W. Picard.

In April 1992, a consortium that includes Honda R&D Co., Ltd., NEC Corporation, and IBM, funded a new $1.7 million, three-year research program entitled "Computer Generated Holograms for Automotive CAD Previsualization," directed by Professor Stephen A. Benton. Alenia-Aeritalia & Selenia S.P.A. of Rome entered into a three-year $650,000 contract for "The Intelligent Design of Multimedia Manuals" directed by Professor Muriel R. Cooper. David Sarnoff Research Center, a subsidiary of SRI International, subcontracted with the Media Lab for a program on "Mid-Level Vision for Image Analysis" under the supervision of Professor Adelson. This research is part of the Sarnoff National Information Display Laboratory Program.

KANSA Corporation, based in Helsinki, initially contracted at the beginning of the year for multi-year support of a research program in "Multi-Media Design Automation" directed by Professor Cooper and "Artificial Insurance Agent" by Professor Davenport. Unfortunately, this program is being canceled after the first year because of changes in KANSA management and direction.

Media Technology Group (MTG) Sponsors
New members of the Media Technology Group during the year included Microsoft Corporation, PIAS Co., Ltd., Reed Publishing, Inc., TeleColumbus AG, and Thinking Machines Corporation. Several former MTG members including CDC/Arbitron, Contel, and Systemsoft completed their membership terms during the year.

Equipment Gift Sponsors
Equipment gifts during the year from Apple Computer, Digital Equipment Corporation, Hewlett-Packard, IBM, Silicon Graphics Corporation, and Sun Microsystems benefited various research groups in the Lab. As FY 1992 closed the Epistemology & Learning Group received a $600,000 equipment gift from the Education and University Relations Corporate Office of IBM to upgrade the computer hardware and software at the Hennigan Public Elementary School in Jamaica Plain, one of the Group's Project Headlight Schools.

A complete list of current Media Lab sponsors appears at the end of this report.

SPACE
Space changes completed during FY 1992 include:

- converting E15-040 (296 sq. ft.) from a storage room to a central computer, file server, and network operations room.
- moving Media Lab, our central electronic mail and time-sharing computer, from the third-floor machine room to E15-040.
- moving the CM2 connection machine from the third-floor machine room to E15-016.

Space changes underway during the summer of 1992 include:

- converting the third-floor former machine room (E15-368) into three offices and a computer garden for the Vision & Modeling Group.
- converting the reading room (E15-401) into four offices and a computer garden/secretarial area for the Music & Cognition Group.

The "Cube" Project
A feasibility study was completed during FY 1992 by the structural engineer for the original design of cube, Leslie E. Robert, Associates (LERA), to determine the feasibility of lowering the Philippe Villers Experimental Media Facility by one level, thereby gaining an additional 4,000 square feet of Media Lab space in the Wiesner Building.

A committee to select an architect was formed; its members included Professors Stephen A. Benton, Nicholas Negroponte, and Seymour A. Papert, and Mr. Robert P. Greene, Media Lab Associate Director for Finance and Administration, together with the collaboration and assistance of Physical Plant representatives. Centerbrook Architects and Planners of Essex, Connecticut, the firm selected for the project, formed an outstanding design team led by partner Mr. Mark Simon.

Centerbrook organized a series of intense workshops, design reviews, and meetings with representatives of each Media Lab group and a Steering Committee over a six-month period. This process resulted in a preliminary design which is being used in discussions with potential sponsors. The plan is to complete fundraising for this $2.5 million project early in FY 1993 so that construction can begin as soon as possible thereafter. The project as now planned involves flooring over the third-floor level of the facility to provide new, readily reconfigurable common space, conference room, library, lounge, and kitchen area, together with new research labs, and computer garden space for the Epistemology & Learning Group; space released by the move of these offices will be renovated into new office and computer garden space.

PERSONNEL

Mr. Joe Cook, Jr., joined the Epistemology & Learning Group as a half-time Research Associate in September 1991. Mr. Cook is concurrently the Director of Paige Academy in Roxbury and coordinator of the Group's Lego-LOGO research there, as well as a project on the relationship between Nintendo games and school learning. Mr. Randy Sargent joined the Epistemology & Learning Group in September 1991 as a half-time Research Specialist focusing on the design and implementation of an updated version of the "Programmable Brick," a small control computer compatible with the LEGO construction technology and the LOGO programming language.

Mr. Bradley Horowitz, a former Media Arts and Sciences (MAS) graduate student, joined the Vision & Modeling Group in January 1992 as a two-year Research Specialist in digital signal processing, computer vision, and computer graphics. Dr. William Freeman joined the Vision & Modeling Group in June 1992 as a two-year Research Associate following the completion of his Ph.D. in MAS, with a special research interest in developing image processing tools to characterize and identify textures in photographs of natural sciences.

Mr. Michael Klug joined the Spatial Imaging Group as a regular Research Specialist during the year with research interests in experimental programs in synthetic holography and with program management responsibilities for several group research programs.

Ms. Valerie Eames joined the Communications & Sponsor Relations Group (CASR) from MITRE Corporation in November 1991 as Information Coordinator. She conducts visits and walkthroughs for many visitors, serves as liaison for the Industrial Liaison Program (ILP), and recently began coordinating all press inquiries and many sponsor inquiries.

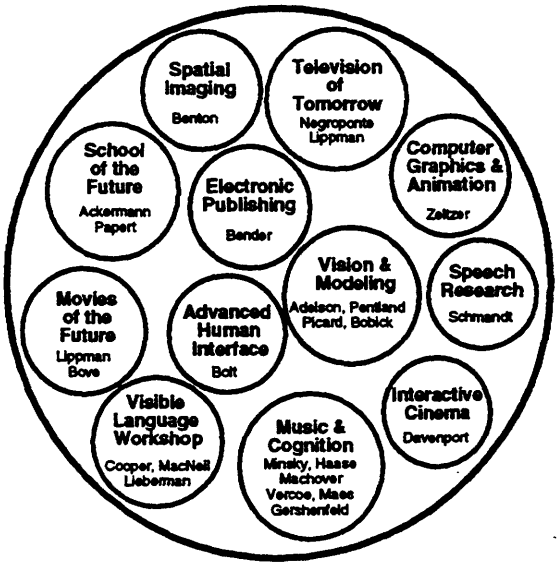
Ms. Carole E. Nassif joined the Finance & Administration Group as Staff Accountant with direct responsibilities for Lab central fund accounts and for organizing, training, and supervising the Lab's financial administrators.

Dr. W. Russell Neuman, who has directed Audience Research activities at the Lab since its inception — most recently as a Principle Research Scientist — begins a new phase in his career in July 1992 as the Edward R. Murrow Professor of International Communication and Director of the Murrow Center at the Fletcher School of Law and Diplomacy, Tufts University. Dr. Neuman will continue to be affiliated with the Media Lab and its Television of Tomorrow (TVOT) program through a continuing research study of the interaction of luminance, contrast, and resolution on viewer perceptions.

Other departures from the Lab during the year include Mr. Giuseppe Labianca, who is entering a doctoral program in management at Pennsylvania State following a temporary one-year appointment in CASR as Staff Assistant with responsibilities for press and special project coordination, and Mr. Walter Sabiston who completed a six-month temporary Research Specialist assignment in the Visible Language Workshop.

Nicholas Negroponte

CURRENT RESEARCH



I. SIGNAL PROCESSING

1. Mid-Level Vision
2. X-Y-T Image Analysis
3. The Analysis of Shading & Reflectance
4. Texture and Pattern Modeling
5. Analysis of Stereo & Egomotion
6. Modeling & Tracking People
7. Portable CAD
8. Paperback Movies
9. Combining Multiple Sources of Range & Motion Info
10. Desktop Movies
11. Movie Datatypes

II. MEDIA TECHNOLOGY

12. Scalable Coding/MPEG-2
13. Panoramic Perspectives
14. Video Visualization
15. Scene Widening/Layered Coding
16. Three-Dimensional Video
17. Listening to Television
18. Open Architecture Television
19. Cheops Imaging System
20. Salient Stills
21. Networked Video
22. Variables in the Viewing Experience
23. Interactive Media in the Home
24. Color Semantics
25. "Paper-Like" Interfaces
26. Wide-Angle Synthetic Holograms
27. Edge-Lit Holograms
28. Holographic Color Control
29. Holographic Video
30. Memory-Based Representation
31. Understanding News
32. Range Sensing Cameras

III. HUMAN INTERFACE

33. Multi-Modal Natural Dialog
34. Knowledge Based Animation
35. Data Glove
36. Tactile Simulation/ Force Feedback Joystick
37. Computers and Telephony
38. Desktop Audio
39. Voice Interfaces to Hand-Held Computers
40. Voice Hypermedia
41. Telephone-Based Voice Services
42. User Modeling
43. Autonomous Agents
44. Interface Agents

IV. APPLICATIONS OF MEDIA TECHNOLOGY

45. Society of Mind
46. Animal Construction Kits
47. Storyteller Systems
48. Iconic Stream-Based Video Logging
49. Multi-Media Testbed
50. Computationally Expressive Tools
51. Graphical Intelligence
52. Large-Scale, High Resolution Display Prototypes
53. Input/Output Considerations
54. Elastic Movies
55. The Electronic Scrapbook
56. New Tools for Directors
57. Context-Based Representation for Video
58. Advanced Interactive Mapping Displays
59. Hyperinstruments
60. Automatic Rhythm Parsing
61. Synthetic Holography for CAD
62. Holograms for Medical Imaging
63. Synthetic Performers
64. Synthetic Listeners
65. Synthetic Spaces
66. Cognitive Audio Processing
67. Structured Audio Transmission
68. Looking At People
69. Fractal-Based Bandwidth Image Coding
70. Exploratory Design
71. Constructionism
72. LEGO/Logo and Programmable Bricks
73. Robot Design Competitions
74. Project Headlight
75. Learning in Multicultural Settings
76. Science and Whole Learning Teachers Collaborative
77. Electronic Communication
78. Children and Machines
79. Children and Artificial Life
80. Children as Designers
81. Games
82. Study of Mathematical Thinking

MEDIA LABORATORY SPONSORS

(as of June 30, 1992 and during FY92)

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

Alenia
Apple Computer
Bell Communications Research
BT
DARPA
David Sarnoff Research Center, Inc.
GoldStar
Interlego A/S
International Business Machines
KANSA Corporation
National Science Foundation
The News Corporation, Ltd.
NHK
Nintendo
NYNEX
PAWS, Inc.
SECOM
Sun Microsystems
Toshiba
Yamaha

CONSORTIA:

Television of Tomorrow
BNR, Inc/Northern Telecom
Deutsche Bundespost Telekom
Eastman Kodak Company
Hughes Aircraft Company
International Business Machines
RAI-Radio Televisione Italiana
Sharp
Sony
Toppan

Movies of the Future
Apple Computer
Bell Communications Research
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Intel
Viacom International
Warner Brothers, Inc.

Computer Generated Holograms for Automotive CAD Previsualization
Honda R&D Company, Ltd.
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Major Equipment Gifts

Apple Computer
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Media Technology Group

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BellSouth Enterprises, Inc.
BT
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Gannett Co., Inc.
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IRI Group
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PIAS, Co., Ltd.
Pioneer Electronic Corporation
Reed International
Roland
SECOM
Seiko Epson
System Soft
Thinking Machines Corporation
TeleColumbus AG
Toshiba

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
IMRF
Interlego A/S
Matsushita
MCA
The Mead Corporation
NEC
Nintendo
Schlumberger
Sony
TIME, Inc.
The Times Mirror
Toshiba
Warner Communications

SCHOOL OF ENGINEERING

The School's major accomplishments this past year involved the creation and support of several new "virtual centers" or programs. In each case there are many activities on campus, but they are often uncoordinated. The programs differ from the traditional interdepartmental centers or laboratories in that they do not occupy significant space, but rely on interactions among faculty and staff in existing centers and departments.

The first program to be announced was the Program in Environmental Engineering Education and Research (PEEER), directed by Professor David Marks. PEEER is intended to coordinate activities in the School in the environmental area. It is also expected to work with the Provost's Council on the Global Environment in order to achieve a coherent Institute-wide program on the environment.

The second such program was the Program in Technology, Management and Policy (TMP), whose director is Professor Daniel Roos. The goal of this program is to coordinate activities in the School in the general area of technology and policy. It is hoped that these activities will extend to other schools in the Institute as well. One of the anticipated accomplishments of the TMP Program is a standing doctoral program in the area of technology and policy.

The third program is the Decision Sciences Program, directed by Professor Thomas Magnanti of the Sloan School with Professor Richard Larson of the Engineering School as the Associate Director. The goal of this program is to coordinate activities in the Institute in a variety of areas of applicable mathematics, such as operations research, statistics, and control.

Over the past year, the Engineering Education Committee actively participated with the Departments of Electrical Engineering and Computer Science (EECS) and Aeronautics and Astronautics as they continued to explore Five Year First Professional degree programs. These programs would lead to a new "Master of Engineering" degree as well as an accredited Bachelor's degree. It is expected that the Engineering Education Committee will bring the proposed new degree title of Master of Engineering forward for approval by the faculty during the coming year. In addition, the Engineering Education Committee discussed the impact of the General Institute Requirements (GIR) on engineering education, methodologies for improving and evaluating teaching quality, and the need for a School of Engineering-wide subject in computation. Discussion of these last three areas will continue into the next academic year.

The Large Scale Systems Committee has continued its discussions. It was split into two groups during the year. One, under the chairmanship of Professor Michael Golay, investigated programs that emphasized public policy issues. These programs would be extensions of the existing Technology and Policy Program to a broader class of students. The other, under Dean Joel Moses, emphasized organizational and design issues. The latter issues are close to the Systems Engineering program under discussion in the Aeronautics and Astronautics Department. Both programs are intended for students who already possess a first professional degree and have several years of industrial experience.

Discussions are continuing of a major new initiative in the telecommunications area. This would involve, in addition to EECS, the Laboratory for Computer Science and the Laboratory for Information and Decision Systems of the Engineering School; the Media Laboratory, the Sloan School of Management, the Political Science Department, and the Lincoln Laboratory. A major research program in fiber optics technology involving the Lincoln Laboratory and the campus as well as Bell Laboratory and the Digital Equipment Corporation was funded this past year by DARPA. Continuing discussions have emphasized the systems and applications of new fiber-based networks.

The Department of Civil Engineering changed its name to the Department of Civil and Environmental Engineering as of July 1, 1992, to highlight the fact that approximately half of its faculty consider themselves to be environmental engineers. The department has also recently added an undergraduate program in Environmental Engineering Science.

AWARDS

The Bose Award for Excellence in Teaching was presented this year to Professors Gerald Sussman and Harold Abelson of the Department of Electrical Engineering and Computer Science for development and teaching of 6.001.

The Ruth and Joel Spira Awards for Teaching Excellence were presented this year to Professor Martha Gray of the Department of Electrical Engineering and Computer Science and HST, Professor Ain Sonin of the Department of Mechanical Engineering, and to Professor Norman Rasmussen of the Department of Nuclear Engineering. The Spira awards were established this year with a gift from Mr. and Mrs. Joel Spira to honor outstanding teachers in the three departments listed above.

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: Mohsinuddin Ansari, EECS; Firdaus Bhathena, EECS; Arturo Fagundo, EECS; Celine W. Fung, EECS; Harold Y. Hwang, EECS; Robert J. Lustberg, EECS; Yanko Sheiretov, EECS; Karl Sun, EECS; Michael Man-Hak Tso, EECS.

Reinhold Rudenberg Memorial Fund - This prize is awarded to students based on their senior theses in the area of energy conversion.

This year's income was sufficient so that this year's award was presented to two students: Andrea Kendrick of the Laboratory for Electromagnetic and Electronic Systems for her thesis entitled: *"Implementation of Template Matching and Fast Wavelet Transform Identification Algorithms"* and Tzu-Jun Yen of the Energy Laboratory for her thesis entitled: *"Electrically Heated Gloves for Indoor Use"*.

ENGINEERING INTERNSHIP PROGRAM

For the summer 1992, 32 sophomores have been placed in the Engineering Internship Program making the total enrollment 82. There are 27 participating company locations.

CONCOURSE PROGRAM

Twentieth Anniversary

On the weekend of September 27-8, 1991 we celebrated the twentieth anniversary of the Concourse Program. The center of attention was an all-day forum entitled, *"Redesigning an Undergraduate Education."* Workshops included *"What should an MIT Education Be?," "What role should a university play in life-long education," "What role should MIT play in reforming K-12 education," and "Under what circumstances would you recommend MIT to a young person?"* The discussions (and the festivities that followed at the Hyatt Pavilion) were greatly enriched by the many distinguished Concourse alumni who were present (some of whom are now MIT faculty) and also those, including Drs. Jerome Wiesner, Merrit Schwartz, Louis Smullin and Jerome Lettvin, who played vital roles in the founding and growth of the program.

Educational Initiatives

During the 1991-92 academic year, a software environment entitled *"The Newtonian Sandbox-Motion Toys for Eye & Mind"* was implemented, using an Athena microcomputer facility. The result was a setting in which students can explore the relationships between their perceptions and their (very often incorrect) intuitions about motion, and compare these with time-dependent representations which are mathematical solutions to Newtonian dynamics. The net effect was positive, although it is obviously too early to reach formal conclusions. Students gained new insights into dynamics which are not common among first year students; new and different kinds of problems could be posed; and the nature and quality of classroom discussion was markedly improved. We will continue to use this software in the 1992-93 year as part of our continuing effort to understand the best uses of computers in undergraduate education.

Faculty and Staff

Members of the Concourse Faculty for 1991-92 were: Professor Robert M. Rose, Department of Materials Science and Engineering; Professor Judah L. Schwartz, School of Engineering and Harvard School of Education; Dr. Daniel Goroff of the Harvard School of Education; Farshid Hajir of the Department of Mathematics; Dr. Gilbert Whittemore and Dr. Mangol Bayat, Writing Program; Dr. Kevin Rhoads and Massimo Russo, Office of the Provost; and Cheryl Butters, Office of the Dean for Undergraduate Education. Each term ten MIT undergraduates were employed as teaching assistants, to teach, to run evening tutorials and to run recitations in chemistry, calculus, physics and differential equations.

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

MINORITY INTRODUCTION TO ENGINEERING AND SCIENCE

In the summer of 1992, 42 high school juniors will attend the MITES Program. 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 A. Douglas Carmichael and coordinated by Mr. William Ramsey.

ENROLLMENT

Changes in enrollment during 1991 continued the trends exhibited in 1990. In 1991 undergraduate enrollment across the School increased by one half of one percent (eleven students), while graduate enrollment decreased by about 1.3% (32 students).

	Undergraduate Enrollment				Graduate Enrollment		
	'91	Change From '90	% Change	Change '89 to '90	'91	Change From '90	% Change
AERO	190	-60	-24%	-16%	212	- 8	- 4%
CHEM	220	46	26%	24%	202	-19	- 9%
CIVIL	113	-10	- 8%	13%	304	32	12%
EECS	917	54	6%	7%	707	9	1%
MS&E	132	6	5	5%	190	1	1%
MECH	438	-21	- 5%	- 7%	419	- 7	- 2%
NUCL	13	- 1	- 7%	-54%	128	-26	-17%
OCEAN	8	- 3	-27%	22%	156	- 8	- 5%
CAES					58	- 6	- 9%
TOTALS	2031	11			2376	-32	

AFFIRMATIVE ACTION

This year, in conjunction with the President and Provost's initiatives for recruiting women and underrepresented minority faculty, each of the departments in the School designated faculty whose responsibility it is to seek women and underrepresented minority candidates for faculty positions. During the year, the Dean and Associate Dean met with both groups of individuals. In addition, the Dean's Office is coordinating production of brochures aimed at recruiting women and underrepresented minorities to its graduate programs.

The School of Engineering continues to rank at or near the top among major engineering schools in terms of representation of women and minorities in the undergraduate and the graduate student bodies. In Fall 1991, 28% of the School's undergraduates were women (572 students); 8% were african americans (158 students), 8% were hispanics, and half of one percent were native americans.

Women constituted 50% or more of the undergraduate enrollment in Chemical Engineering (121 women, 55%), Materials Science and Engineering (66 women, 50%), Nuclear Engineering (8 women, 62%), and Ocean Engineering (4 women, 50%).

Despite the fact that the School compares favorably with sister institutions, the percentages are still unsatisfactory, particularly among the graduate student population which is only 17% female (385 students), 1.5% african american (34 students) and 1.5% hispanic (35 students).

At the start of the academic year, there were 18 women among the School's faculty. During the year, faculty positions were offered to six women (32% of all faculty offers), five of whom accepted those offers, bringing the number of women on the School's faculty to 23. In the course of a telephone survey conducted by the Dean's Office this year, it was discovered that the School of Engineering ranks close to the top among major engineering schools in terms of representation of women on its faculty. We expect that with these new hires, the percentage of women faculty in the School will be higher than all of our sister institutions.

The number of underrepresented minorities (african american, mexican american, puerto rican, and native american) among the School's faculty remains unchanged at four. During 1991-92 one underrepresented minority candidate was offered a faculty position in the School. Unfortunately, that offer was declined.

The deliberations of the Presidential Task Force on Career Development of Minority Administrators focussed attention on this segment of the population. There are currently four underrepresented minorities among the School's administrative staff (up from one in 1982). All four are african americans. Analysis of changes in the support staff since 1989 indicates that underrepresented minorities among the support staff have been promoted at rates which exceed their representation on the support staff.

Faculty Size
Across the School, thirteen individuals were named to faculty positions. With thirteen departures, the School's faculty size remained constant. Over the past seven years the number of authorized faculty positions in the School has decreased about 6% from 391 to 368.

School Professors
Nicholas Ashford was promoted to Professor in the School of Engineering effective July 1, 1992. Louis Bucciarelli, Jr. was named co-Director, along with Arthur Steinberg, of the Integrated Studies Program.

Engineering Council
Professor David N. Wormley resigned his position as associate dean to become Dean of Engineering at Penn State University. He is succeeded as associate dean by Professor John B. Vander Sande, Cecil and Ida Green Distinguished Professor and Professor of Materials Science and Engineering. Professor David H. Marks resigned his position as head of the Department of Civil and Environmental Engineering to assume the position of Director of the Program in Environmental Engineering Education and Research (PEEER). He is succeeded as department head by Professor Rafael L. Bras, William E. Leonhard Professor of Engineering and Professor of Civil Engineering. Professor Daniel Roos was named director of the Program in Technology Management and Policy (TMP). Professor Roos will also continue to serve as director of the Center for Technology, Policy and Industrial Development (CTPID). Professor Yosef Sheffi, Professor of Civil Engineering was named director of the Center for Transportation Studies (CTS). He succeeds Professor Joseph M. Sussman who returned to regular faculty status as J.R. East Professor and Professor of Civil Engineering. Professor Richard C. Larson, Professor of Electrical Engineering, joins Engineering Council this year as the first associate director of the Program for Decision Sciences.

JOEL MOSES

Department of Aeronautics and Astronautics

During the 1991-92 Academic Year the department expended considerable effort on the implementation of its strategic plan, with particular attention being directed towards the revised curriculum for the Bachelors of Science Degree and the planning for two new masters degrees. Many aspects of department life for students and faculty were also addressed. Our faculty ranks increased by one with the addition of three new assistant professors and the departure of two associate professors. Many faculty were recognized for noteworthy contributions. The department welcomed six visiting faculty members and several distinguished speakers. 64 students received the Bachelors of Science Degree and many of our undergraduates were recognized for outstanding accomplishments. Sixty-one Masters, and 26 Doctoral degrees were awarded. Approximately 200 sponsored research projects totaling $10 million led to many interesting results during the year. The department was pleased to learn that the *US News and World Report* Rankings again rated it as the top aerospace engineering department in the country.

IMPLEMENTATION OF THE STRATEGIC PLAN

The department strategic plan introduced in last year's annual report contains 35 recommendations for curriculum changes, new research programs, improvement to department life, and external relationships. Most of the 35 recommendations were acted upon to some extent during the 1991-92 academic year with the major activities being:

A committee co-chaired by Professors Edward Crawley and Sheila Widnall during the summer and fall semesters, and Professors Crawley and Edward Greitzer in the spring semester, developed a detailed plan for the revision of the S.B. degree and creation of a new Masters of Engineering Degree. The draft of the plan developed during the summer of 1991 was extensively debated and strengthened during numerous faculty gatherings and working group activities involving nearly the entire department faculty. A final draft of the plan for these new degrees will be completed early in the next academic year.

Professor Amedeo Odoni chaired a committee to develop the preliminary plan for a new professional Masters degree in Aerospace Systems Engineering. By academic year end, the committee had presented its plans to the School of Engineering Large Scale Systems Engineering Degree committee chaired by Dean Joel Moses. The Odoni committee also laid the foundation for offering a one-month course in January 1993 which would serve as a prototype for this new degree.

The Undergraduate Policy Committee chaired by Professor Winston Markey implemented the first versions of early warning and tutoring programs for the core undergraduate subjects. In an effort to more directly interface with the freshmen and their academic programs, 14 department faculty served as freshman advisors, and Professor James McCune took on the responsibility of Coordinator with the freshman year program. A subcommittee chaired by Professor Paul Lagace began to consider ways of improving departmental undergraduate advising.

The Graduate Committee chaired by Professor Harold Wachman introduced a new Teaching Fellows program to attract well qualified graduate students for a semester or a year of teaching assistantship. In the program's inaugural year, the six teaching fellows shared a dinner discussion with the 1991 winner of the School of Engineering Bose Award, Professor Alvin Drake of the Electrical Engineering and Computer Sciences Department. The Outreach Subcommittee co-chaired by Professors Daniel Hastings and Lena Valavani actively worked to inform our own undergraduates about graduate school opportunities, and to attract a greater percentage of women and underrepresented minority students to our graduate degree programs. Their efforts resulted in enrollment of 29 women and 6 underrepresented minority students for the fall 1992 term.

In recognition of the growing importance of international aspects in the education of engineers, Professor Manual Martinez-Sanchez was appointed as Coordinator for International Education. Various activities were undertaken to gather information on existing international programs and to make initial contact with colleagues in foreign universities. Student exchanges with Moscow Aviation Institute continued under the direction of Professor Crawley.

A Resource Development committee chaired by Professor Earll M. Murman was established. During the year, the committee built relationships with MIT's resource development offices, set priorities for fund raising and made contact with potential donors. The creation of senior faculty chairs to help "harden" faculty salaries and increasing company participation in the Engineering Internship Program were established as top priorities.

A mentoring committee chaired by Professor Murman was created to focus continuing attention on the career growth of our junior faculty members. It was actively engaged in this process during the academic year. One accomplishment was that all new assistant professors now have career development chairs and other sources of discretionary funds to initiate new research programs and subject offerings.

Ad hoc working groups discussed directions and plans for the two research areas identified in the strategic plan for significant growth. Professor Lagace chaired the working group on Engineered Materials, and Professor John Hansman and Dr. Milton Adams co-chaired the one on Aerospace Information, Decision and Control.

FACULTY NOTES

Professor Emeritus Judson R. Baron was elected a Fellow of the American Institute of Aeronautics and Astronautics (AIAA).

Professor Peter Belobaba was named a Charles Stark Draper Assistant Professor for two years starting January 1992. Effective July 1, 1992 he will become Chairman of the Masters of Science in Transportation Program in the School of Engineering.

Professor Kenneth S. Breuer was named a Charles Stark Draper Assistant Professor for two years starting July 1991.

Professor Eugene E. Covert received the AIAA W. F. Durand Lectureship Award and delivered the talk *Research and Engineering at the Turn of the Century - Meeting the Challenge* at the AIAA Annual Meeting on April 29, 1992.

Professor Edward F. Crawley was named as one of the first six Institute MacVicar Faculty Fellows, recognizing his exemplary and sustained contributions to under graduate education. He was a co-recipient of the Organization Scientifique et Technique International du Voile a Voile Diploma at the 1991 World Soaring Championships for work done on defining crashworthiness requirements and improved crashworthy fuselages for sailplanes.

As faculty advisor and pilot for the MIT Human-Powered Hydrofoil Team, Professor Mark Drela set a world speed record of 18.5 knots for human -powered watercraft.

Professor Alan H. Epstein was a co-recipient of the 1991 Turbomachinery Committee best paper award at the International Gas Turbine Conference of the American Society of Mechanical Engineers (ASME).

Professor Michael B. Giles resigned from the faculty to accept a position as Reader in Computational Fluid Dynamics at Oxford University.

Professor Edward M. Greitzer was elected a fellow of the AIAA and was a co-recipient of the 1991 Turbomachinery Committee best paper award at the International Gas Turbine Conference of the American Society of Mechanical Engineers (ASME).

Professor Nesbitt W. Hagood IV joined the faculty on July 1, 1991 as a Charles Stark Draper Assistant Professor in the Structures, Materials and Aeroelasticity Division

Professor R. John Hansman was on sabbatical for the fall semester. He was a co-recipient of the Organization Scientifique et Technique International du Voile a Voile Diploma at the 1991 World Soaring Championships for work done on defining crashworthiness requirements and improved crashworthy fuselages for sailplanes.

Professor Daniel E. Hastings was selected by the YMCA of Greater Boston as one of two Black Achievers at MIT for 1992. In a move to bring together the aerospace computational research in the department, together with colleagues he formed the Computational Aerospace Sciences Laboratory.

Professor Walter Hollister became Acting Head of the Biomedical Engineering Division of Instruction during the leave of absence of Professor Young.

Professor Jack Kerrebrock received the Leland Atwood Award for Aerospace Education from the American Society of Engineering Education (ASEE) and the AIAA. He was appointed as Chairman of the Space Station Advisory Committee of the National Research Council. The second edition of his book on *Aircraft Engines and Gas Turbines* was published.

Professor Paul Lagace received the American Society of Testing Materials (ASTM) Committee D30 Best Presentation Award.

The second edition of Professor Mårten Landahl's book *Turbulence and Random Processes* co-authored with Professor Mollo-Christensen appeared in the summer of 1992.

Professor Emeritus James Mar was elected an Honorary Fellow of the AIAA.

Dr. Charles M. Oman was appointed as Director of the Man-Vehicle Laboratory.

Professor James D. Paduano joined the faculty in January 1992 as a Charles Stark Draper Assistant Professor in the Instrumentation, Guidance and Control Division. He was a co-recipient of the 1991 Turbomachinery Committee best paper award at the International Gas Turbine Conference of the ASME.

Professor Emeritus Theodore H. H. Pian received an Honorary Degree from Shanghai University of Technology.

Professor Leon Trilling was on sabbatical. He was a member of the Visiting Committee for the Science, Technology and Society Program at Vassar College.

Professor Andreas von Flotow resigned from the faculty to begin his own consulting business and become an Adjunct Professor at the University of Washington. He was on sabbatical for the spring semester.

Professor Ian A. Waitz joined the faculty on July 1, 1991 as an assistant Professor in the Propulsion and Energy Conversion Division. He was appointed the Rockwell International Career Development Professor for three years starting November 1991.

Professor Sheila E. Widnall was appointed as Associate Provost for the Institute in January 1992. She was elected a Council member of the National Academy of Engineering for a three year term. She served on the National Research Council Engineering Education Board and as a member of the National Academy of Science/National Academy of Engineering Committee on Science, Engineering and Public Policy.

Professor Lawrence R. Young was granted a leave of absence upon his selection as a NASA Payload Specialist for the Space Life Sciences 2 Shuttle Mission for mid 1993. He was also elected a member of the Institute of Medicine.

VISITING FACULTY

The department welcomed two distinguished visitors as Jerome C. Hunsaker Professors of Aeronautics and Astronautics. This is the first time in the history of the Professorship that there have been two simultaneous appointments.

Dr. Nicholas A. Cumpsty, on leave from the Department of Engineering at Cambridge University where he is Director of the Whittle Laboratory, was in residence in the Gas Turbine Laboratory. Professor Cumpsty delivered the fall 1991 Minta Martin Lecture on *Aerodynamic Problems of Aircraft Engines: Strides and Some Stumbles.*

Dr. Stanley I. Weiss, recently retired as Vice President and General Manager of Research and Development for Lockheed Missiles and Space Company, delivered the spring 1992 Minta Martin Lecture on *Sensors in Aerospace Systems.* While in residence he taught undergraduate and graduate subjects and was actively involved in implementation of the strategic plan. During the year he was honored by his undergraduate and graduate alma maters. Rensselaer Polytechnic Institute gave him the Distinguished Alumni Fellow award from the Department of Mechanical Engineering, Aeronautical Engineering and Mechanics. The University of Illinois College of Engineering recognized Dr. Weiss with the Alumni Honor Award for Distinguished Service in Engineering.

Other scholars from around the United States who were also in residence are:

Dr. Milton B. Adams joined the department as a lecturer for the Academic Year while taking a leave of absence from the Charles Stark Draper Laboratories. He introduced a new subject *16.42- Large Scale Information and Decision Systems* in the spring semester.

The Gas Turbine Laboratory welcomed Professor Reiner Descher of the University of Washington for the fall semester and Professor Jim Johnson from Stanford University in the spring semester.

The Space Engineering Research Center hosted Professor K. C. Park from the University of Colorado and Professor Alok Sinha from Pennsylvania State University during the spring semester.

LECTURES AND DEPARTMENT SEMINARS

David W. Thompson '76, President of Orbital Sciences Corporation, delivered the third Space Grant Lecture titled *"The Microspace Revolution."* Mr. Thompson was awarded the National Medal of Technology last year by President Bush.

Col. Kenneth Cameron S.B. '78 and S.M.'79, pilot of the Space Shuttle *Atlantis* presented a lecture in the fall semester on *"Space Shuttle Mission STS-37."*

Dr. Byron Lichtenberg Sc.D. '79, payload specialist aboard Space Shuttle *Atlantis* presented a lecture in the spring semester on *"Space Shuttle Mission STS-45."*

The fall semester Department Seminar Series featured the following talks on the National Aerospace Plane:

An Overview of the NASP Program by Dr. Robert Barthelemy, Director of the NASP Program Office

Materials and Structures Technology for NASP by Dr. Terry Ronald of the NASP Program Office

Aerodynamics for the NASP by Dr. Lawrence Edwards of NASA Langley Research Center

Hypersonic Propulsion by Dr. Lamar Moon of Rockwell International Corp.

UNDERGRADUATE PROGRAM

Undergraduate Enrollment over the Last Nine Years

	1983-4	1984-5	1985-6	1986-7	1987-8	1988-89	1989-90	1990-91	1991-92
Soph.	100	99	106	120	96	103	75	76	61
Juniors	81	90	92	103	118	94	87	61	62
Seniors	81	93	106	98	105	130	104	104	73
Totals	262	282	304	321	319	327	266	241	196
% of women	19%	18%	18%	16%	19%	21%	25%	23%	27%
% of underrep. minority students	10%	10%	11%	10%	N/A	14%	18%	20%	14%

Several students were selected for named scholarships based upon their outstanding academic record and contributions to the department:

Mr. Buford Conley '93	John F. McCarthy Scholarship
Ms. Celia H. Liu '92	James Cunningham Scholarship
Mr. Michael L. O'Connor '92	James Doolittle Scholarship
Ms. Cecelia H. Park '93	John H. Wykes Memorial Fund Scholarship

The National Science Foundation's *"Incentives for Excellence"* scholarships were given to Paul Engola, Homero Gutierrez, and Matthew Velaquez.

Two Course XVI undergraduates were recognized at the Institute Awards Convocation in May:

Laya W. Wiesner Award
For an undergraduate woman who has enhanced MIT community life was given to

Amy R. Pritchett '92

Howard W. Johnson Award
For the male senior athlete of the year was given to

Thomas A. Washington '92

Department undergraduate awards are listed below:

Henry Webb Salisbury Award
This award established in the memory of Henry Webb Salisbury ('33) is given annually to a graduating senior in Course 16 for the highest degree of academic achievement. This year's winner is:

Michael L. O'Connor '92

James Means Memorial Prize
For excellence in Flight Vehicle Engineering

Reynaldo Villarreal '92

For excellence in Space Systems Engineering

Maysoon E. Kader '92

Admiral Luis De Florez Award
Awarded to undergraduates who have demonstrated "original thinking or ingenuity" in Aeronautics and Astronautics. This year's winners are:

Alison J. Williams '92
Adam S. Lechner '92
Maysoon E. Kader '92
Paul J. Stach '92

Unified Engineering Award
For outstanding devotion to and leadership of the team of student assistants in Unified Engineering, as well as skillful organization and planning to achieve smooth operation of the complex Unified Engineering enterprise.

Amy R. Pritchett '92
Johan C. Denecke '92

Andrew G. Morsa '87 Award
For demonstrated ingenuity and initiative in the application of computers to the field of aeronautics and astronautics

No Winners for 1991-92

Leaders For Manufacturing Undergraduate Prize
For demonstration of the relation between manufacturing and technical performance through determination of the influence of manufacturing irregularities on the aerodynamic performance of airfoils.

Sergiu V. Tofanel	'93
Reynaldo Villarreal	'92

GRADUATE PROGRAM

A total of 244 applications were received for the Fall 1991 term. Out of this, 122 were admitted and 70 accepted the offer of admission. Enrollment for Fall 1991 included 136 S.M., 69 Ph.D., 2 EAA degree candidates for a total of 207. Total of minority students 5 (2 Ph.D., 3 S.M.). Total of women 19 (4 Ph.D., 15 S.M.). In the Spring 92 term, there were 40 applications. We admitted 22 out of 40 and 15 enrolled. Four women applied, 3 were admitted and 2 enrolled. Three minority applied, 1 was admitted and 0 enrolled. Enrollment for Spring 1992 was 201 which included: 132 S.M., 68 Ph.D., 1 EAA. Total women: 18 (3 Ph.D., 15 S.M.). Total minority: 5 (2 Ph.D., 3 S.M.).

	Degree Granted			
Semester	S.M.	EAA	Ph.D.	Total
Summer	21	0	2	23
Fall	14	0	5	19
Spring	26	0	19	45
Total	61	0	26	87

Six students, selected as the first Departmental Teaching Fellows were:

Andrew Barrows	Charles Stark Draper Teaching Fellow
Adam Dershowitz	Jerome C. Hunsaker Teaching Fellow
Sasi Digavalli	Theodore von Karman Teaching Fellow
Chantal Moore	Charles Stark Draper Teaching Fellow
David Oh	Edward S. Taylor Teaching Fellow
Brian Teeple	Raymond L. Bisplinghoff Teaching Fellow

The Teaching Fellows Program is partially supported by the Course XVI Alumni/ae Graduate Fellowships Fund which grew during the year by $31,565 from generous donations by our former students.

Mr. Andrew Lewin was awarded a Marshall Scholarship and will attend Cranfield Institute of Technology in England for two years. He was one of only 40 winners for this prestigious national scholarship.

Funding for graduate students is summarized in the table below.

Funding	Fall 1991	Spring 1992
DOD & ONR Fellows	10	9
NSF Fellows	8	7
AFRAPT Fellows	8	7
Dept., Space Grant, LFM, Outside, Minority,Fellows	16	16
Draper Fellows	27	29
Research Assistants	95	90
Teaching Assistants/Fellows	9	9
Self	21	22
Foreign	9	8
EIP	4	4
Totals	207	201

MIT SPACE GRANT PROGRAM
Director: Professor Daniel Hastings

The MIT Space Grant Consortium grew with the addition of the Harvard/Smithsonian Astronomical Observatory and Wellesley College. Harvard/SAO will develop a program to allow high school students all over the country to access automatic telescopes in Arizona to request specific observations and receive help in interpreting the data. Wellesley College will send students to participate in Space Grant funded Undergraduate Research Opportunities Program (UROP) as well as the summer positions in the participating companies. At MIT, the program "graduated" its first class of 23 seniors who have been associated with the program since their sophomore year. Almost 80 percent chose to go on to graduate school. The Program was able to offer graduate fellowships to three of these seniors. A highlight of the spring semester was the Program sponsored a public lecture by Mr. David Thompson on the "Microspace Revolution".

RESEARCH LABORATORIES

Aeronautical Systems Laboratory (ASL)
Director: Professor John Hansman

The work within the ASL over the past year has focused in the areas of cockpit information management, situational awareness, automated planning systems and hazardous weather avoidance. The information management activities include studies of situational awareness in the dissemination of hazardous weather alerts, air traffic control (ATC) clearance amendments, and in using digital datalinks and evaluation of information requirements for advanced electronic instrument approach charts. The hazardous weather avoidance activities have focused on microburst and ice accretion alerting systems as well as fundamental aircraft ice accretion studies. Situational awareness studies have focused on advanced terrain alerting systems. Aircraft icing activities have received renewed outside interest due to several recent aircraft icing related accidents. Several patents were allowed or issued for aircraft ice detection; one for indicating de-icing fluids has received much attention after the USAir F-28 accident at La Guardia.

Computational Fluid Dynamics Laboratory (CFDL)
Director: Professor Michael B. Giles

Fourteen graduate students, four faculty and a research engineer are developing and applying methods for the computational modeling of aircraft, rotocraft and turbomachinery flows. The success of the Human-Powered Hydrofoil design (see Faculty Notes for Prof. Drela) depended in large part on extensive numerical simulation and design of the supporting hydrofoil profiles using CFDL software. The visualization package VISUAL3 developed by Robert Haimes is being adopted by a large number of government and industrial organizations. VISUAL3 is unique in being designed for steady and unsteady, volumetric scalar and vector data on a wide variety of types of computational grids. Professor Michael Giles moved to Oxford University to take up a position as Reader in Computational Fluid Dynamics. A search is underway for a new faculty member in CFD.

Fluid Dynamics Laboratory (FDL)
Director: Professor Mårten Landahl

Research continued on understanding fluid flow instability, transition to turbulence and turbulence structure, turbulence modeling, and active flow control. Professor Landahl presented new theoretical results at an international meeting in Ascona, Switzerland on formulating the space-time evolution of localized three-dimensional disturbances in the near wall region of a boundary layer. The old low-turbulence wind tunnel was removed from the laboratory in Building 41 and transferred to Ohio State University. Professor Breuer has designed and built a new one of the open return type. It is expected to be operational in 1992.

Flight Transportation Laboratory (FTL)
Director: Professor Robert Simpson

FTL research in the airline area continues with Delta and Air Canada to develop improved demand modeling, revenue optimization, and seat inventory control systems. Work was completed on a grant from NASA Langley for the impacts of technology on capacity improvements in the United States national airspace system. A study is underway for Douglas Aircraft Company which will use FTL computer scheduling tools to generate various High Speed Civil Transport scenarios. In the Air Traffic Control Area (ATC) area, work is underway focusing on the integration of flight management systems into advanced ATC operations., including investigating potential errors arising from the use of nonstandard phraseology in ATC communications. Work is beginning on a grant from the FAA Technical Center in Atlantic City to develop methods of collision risk analysis for various ATC operational environments.

Gas Turbine Laboratory (GTL)
Director: Professor Edward M. Greitzer

During the past year the GTL continued its emphasis on the "smart engines" project. Two features of this work were the increased focus on transitioning some of the methodology to practical situations and the first use, as far as we know, of an actively controlled compressor as a diagnostic tool to investigate the unsteady fluid dynamic behavior of these devices. A paper on active control of axial compressors, jointly authored by GTL and Cambridge University faculty, was judged the best paper in turbomachinery for 1991 by the American Society of Mechanical Engineers (ASME) Turbomachinery Committee (See Faculty Notes). The addition of Professor Waitz to the GTL has strengthened the efforts on mixing enhancement through embedded streamwise vorticity, an area that has implications for High Speed Civil Transport noise control. Over 30 graduate students, 7 faculty, 6 research staff , and several visitors (see Visiting Faculty) participated in the overall program, which includes strong complements of experiment, computation, and analysis. Finally, the GTL was host in May 1992 to a NATO Advisory Group for Aerospace Research and Development (AGARD) Lecture Series on Engine Performance, which brought roughly seventy specialists to MIT.

Laboratory for Space Teleoperation and Robotics (LSTAR)
Director: Professor Harold Alexander

LSTAR has demonstrated an operational, neutrally- buoyant, space robot simulator. This submersible vehicle includes a vision-based controller for position and orientation and supports research in autonomous and supervisory control for both space and marine remote robots. This project is supported by the Charles Stark Draper Laboratory as a part of their program in autonomous remote submersibles. Professor Alexander also conducted an experiment on the International Microgravity Laboratory-1 (IML-1) Spacelab mission to examine on orbit cognitive and motor performance of astronauts, and the performance affects of micro gravity and micro gravity adaptation. The eight day IML-1 mission flew in January 1992.

Man-Vehicle Laboratory (MVL)
Director: Dr. Charles M. Oman

In June of 1991, a major experiment on human vestibular function was flown on the 10 day Space Life Sciences-1 (SLS-1) Spacelab mission. A dozen graduate students, faculty, and staff actively participated, in addition to collaborators from Boston University and McGill. Results were presented by Drs. Young, Oman, and Merfeld at a 1992 international meeting in Czechoslovakia. In January, 1992, Dr. Oman conducted an inflight rotating chair experiment as part of the International Microgravity Laboratory Spacelab mission. Dr. Oman was appointed MVL Director in January 1992 upon the selection by NASA of Professor Young for a SLS-2 payload specialist (see Faculty Notes). Dr. Lyman Hazelton joined the laboratory staff to direct the "Principal Investigator in a Box" expert systems project which will also fly on SLS-2. Dr. Donald Kaiser, a visiting engineer from Boeing participated in the PI in a Box project. MVL has 10 graduate students, 12 undergraduate UROPers, and several affiliates including Dr. Greg Zacharias and Dr. Conrad Wall.

Space Engineering Research Center (SERC)
Director: Professor Edward F. Crawley

One of the highlights of the past year, was the successful launch of SERC's first Shuttle flight experiment, called MODE, for the Mid-deck 0-G Dynamics Experiment. MODE flew aboard the Shuttle *Discovery* (STS-48) in September 1991, and yielded fundamental data on the behavior of nonlinear fluid slosh and structural dynamic behavior in zero-gravity. MODE will refly in the summer of 1993. SERC continues to work on a second Space Shuttle experiment, MACE, for the Mid-deck Active Control Experiment scheduled to fly in 1994. The purpose of MACE will be to develop the capabilities to minimize disturbances in an Earth-observing platform, so that on-board science instruments can conduct precision scanning and pointing tasks. Eleven faculty, 30 graduate students, a comparable number of UROPers, and several visitors (see Visiting Faculty) participated in the activities of SERC. They are drawn from the Departments of Aeronautics and Astronautics, Electrical Engineering and Computer Science, and Mechanical Engineering. SERC is involved in various outreach programs to secondary schools as well as MIT "Arts-Science Interface Performance" program.

Space Power and Propulsion Laboratory (SPPL)
Director: Professor Daniel Hastings

The SPPL consists of 15 S.M. and Ph.D. students and three faculty members. This year the SPPL expanded into the area of nuclear propulsion in conjunction with colleagues in the Nuclear Engineering Department. A potentially major instability in particle bed reactors for space propulsion was identified and is under investigation. In the area of electric propulsion, a complete numerical simulation of an MPD thruster showed for the first time where some of the inefficiencies are occurring in the thruster plasma dynamics. In spacecraft-environmental interactions, work at the SPPL provided a possible explanation for the anomalous ionization observed in thruster and gas releases in the space environment. This work will be combined with a three dimensional model of a plasma cloud expansion from a spacecraft to provide a comprehensive picture of a gas and plasma release from a spacecraft.

Technology Laboratory for Advanced Composites (TELAC)
Director: Professor Paul Lagace

During the academic year, over 40 students were involved with TELAC including 16 graduate students, 18 UROPers, and a number of students in 16.621/2 Experimental Projects I, II who performed their projects in TELAC. Two Ph.D. and five S.M. thesis were accepted, and the laboratory issued a total of 13 reports, a number accepted for publication in journals and proceedings. Seven presentations were given at conferences with one receiving special recognition (see Faculty Notes for Lagace). Major research accomplishments during the year included the formulation and proposition of a technique to measure the impact damage resistance of composite laminates, development of a methodology to predict the large amplitude/large deflection response of composite structures subjected to aerodynamic loading (such as in the case of helicopter rotor blades), and further understanding of the issues associated with the damage tolerance of composites as used in pressurized construction (such as aircraft fuselages).

Wright Brothers Wind Tunnel Facility (WBWT)
Director: Professor Eugene Covert

The Wright Brothers Facility conducted five major wind tunnel programs this year. One was a pedestrian level wind study, two were associated with vortex shedding from cylinders, and two were anemometer calibration studies. One of the latter was the anemometer used by the America's Cup Winning boat, the America Cubed. These activities required employment of four students. The wind tunnel was also used for six projects associated with the department's project laboratory subject 16.622 Experimental Projects II. Associate Director Emeritus Frank Durgin continues to be actively involved in the preparation of a revised American Society of Civil Engineers manual on Wind Tunnel Modeling of Buildings and Structures.

EARLL M. MURMAN

Department of Chemical Engineering

The Department of Chemical Engineering made significant strides to increase the quality of teaching and enhance our already vigorous research programs during the 1991-92 academic year.

The department completed its review of the chemistry content in the undergraduate curriculum and implemented most of the changes we sought to make to our undergraduate program. As a result of the recommendations of an ad-hoc committee in the department we proposed several changes to our undergraduate program; these included replacing a departmental subject in thermodynamics (10.13 Chemical Engineering Thermodynamics I) with the equivalent subject in chemistry (5.60 Thermodynamics and Kinetics), adding a second semester of organic chemistry (5.13 Organic Chemistry II), and teaching our introductory subject on the use of computers in chemical engineering (10.001 Introduction to Computer Methods) only during IAP. We presented these recommendations to the Committee on Curriculum (COC) and the Committee on the Undergraduate Program (CUP) during the winter and received permission to implement the first two changes, but not to teach 10.001 solely during IAP. We are able to implement these changes while maintaining the cap on the total number of units and the 48 units of unrestricted electives in our program by requiring that chemical engineering majors use 5.11 to satisfy the Institute Chemistry requirement.

The implementation of these changes in the Fall of 1992 marks the most significant change in our curriculum in the last two decades and fulfills previous recommendations of the faculty and our visiting committee, which are based on the belief that a deep knowledge of organic and physical chemistry is a trademark of chemical engineering that will serve us well in the next century.

Our graduate programs continue to operate at a high level of activity and to attract the very best students from around the world. This year 32 doctoral degrees were awarded, along with 24 master's degrees from the David H. Koch School of Chemical Engineering Practice. The Practice School continued operation of stations at the West Point, Pennsylvania manufacturing plant of Merck Sharpe and Dohme and at the Midland, Michigan plant of Dow Chemical Corporation. Our entering class of 37 graduate students was funded initially by fellowship support from our industrial fellowship program, from the Practice School fellowship endowment, and from alumni/ae contributions.

Two events in our graduate research program are especially significant because they reflect the high visibility of our research programs in environmental assessment and remediation. Professors Jefferson W. Tester, Jack B. Howard, Adel F. Sarofim, Kenneth A. Smith, and Jonathan G. Harris have been awarded a 5-year grant by the Army Research Office University Research Initiatives (URI) for research in water oxidation for the treatment of military toxic wastes. In addition, an EPA Center of Excellence for Exploratory Environmental Research has been awarded to M.I.T. Professor Adel Sarofim will serve as director of the new center, which includes participation from the California Institute of Technology and the New Jersey Institute of Technology.

There have been several changes in departmental personnel this year. First, Professor Lawrence B. Evans retired from the Institute to become President of Aspen Technologies, Inc., which markets the world's most used chemical process simulation software; Professor Evans is continuing his association with M.I.T. as an Adjunct Professor in the department. Professor Charles N. Satterfield retired in July 1992 at the age of 70, after a 50 year association with the department first as a student and later as a faculty member. He will continue to teach in the department as a Senior Lecturer. Finally, Professor Jeffrey L. Feerer, an Assistant Professor in the department, left in June 1992 for a position at Dow Chemical Company in Midland, Michigan.

The department concluded its search for a senior faculty member with interest in chemical engineering and public policy with the hiring of Professor Gregory J. McRae as the Joseph R. Mares Professor of Chemical Engineering beginning June 1, 1992. Professor McRae was a faculty member in the Departments of Chemical Engineering and Engineering and Public Policy at Carnegie Mellon University and is an expert in the simulation of urban air quality and in the use of simulation as a tool for air quality management. He will add greatly to the growing environmental program within the department and the Institute. The department also concluded a search for a junior faculty member in process systems engineering with the hiring of Dr. Paul I. Barton. Dr. Barton, who will join the department in the Fall, recently completed his doctorate at Imperial College and is an expert in process simulation.

Two open positions for junior faculty members in the department were dissolved. This decrease in the size of the faculty made it possible to increase the department's support of the academic year salary for a large portion of the faculty. Most notably, the academic year salary of all junior faculty is now totally supported by Institute general funds and by endowment. Each junior faculty member has been told that this situation will continue as long as they are on the faculty.

Several department faculty received special recognition. Professor Robert C. Armstrong, Executive Officer of the department, won the Professional Progress Award from the American Institute of Chemical Engineers (AIChE). Professor Robert S. Langer won the Charles Stine Award from the Materials Division of the AIChE and was elected to both the National Academy of Engineering and the National Academy of Science, and thus joins a very small group of those who have been elected to all three organizations of the National Academy.

UNDERGRADUATE EDUCATION

The following table shows the trends in undergraduate enrollment:

	87-88	88-89	89-90	90-91	91-92
Sophomore	38	47	60	67	96
Junior	36	36	46	60	72
Senior	55	47	34	47	58
TOTAL	**129**	**140**	**140**	**174**	**226**

Chemical Engineering undergraduate enrollment continues the rapid rise that began with academic year 1987-88. This year's enrollment is up more than 70 percent from that time to the present 226. This year the total number of majors rose 26 percent alone, with an increase of 36 percent in the sophomore class accounting for most of the change. Our projections for next year's sophomore class are for about 110 students; thus we do not yet see an end to the increasing total.

In the face of the large increases in student numbers, we are working hard to maintain small class sizes and improve the quality of undergraduate education. This year we began the process of splitting our large undergraduate required laboratories, 10.26 Chemical Engineering Projects Laboratory and 10.27 Chemical Engineering Processes Laboratory, into two parallel sections in order to maintain small laboratory groups. To provide adequate supervision for the increased number of groups we have added additional faculty to the teaching team for these subjects: two additional faculty were added for this year and five are slated for next year. 10.67 Polymer Science Laboratory was also divided into two sections this year. Although listed as a graduate subject, 10.67 has long been popular with our undergraduates; in order better to serve the undergraduates we will be offering a special undergraduate version of this subject next year as 10.467. Professor Edward Merrill has worked hard to design a new set of experiments for this purpose.

Integrated Chemical Engineering

An important part of our 10.491 Integrated Chemical Engineering (ICE) subject is the close interaction of undergraduates and faculty in the design process. Students must take three month-long design modules, each dealing with a different area of technology. In this subject our solution for maintaining good faculty/student contact is to add additional module offerings from which the students can select. Although this puts a higher demand on faculty for teaching, it offers the students more choice in picking technology areas of interest as well as keeping the student/faculty ratio down. During the spring 1992 semester, we experimented with seven module offerings from which each student chose three. These included "Treatment of Brain Cancer Using Controlled Drug Release" (Professor Robert Langer), "Design of an Artificial Gill for Humans" (Visiting Professor Edward Cussler), "Poly Bead Corporation - Product Design for Chromatographic Separations" (Professor Edward Merrill), "Gilson Road Toxic Waste Site - Modeling and Treatment of Chemical Spills" (Professors Kenneth Smith and Herbert Sawin), and "Molecular Based Design of Engineering Polymers" (Professor Gregory Rutledge). Next year we plan to offer an additional module during IAP to allow students extra flexibility in balancing their academic load.

GRADUATE EDUCATION

The following table shows graduate enrollment from 1987-1992:

	87-88	88-89	89-90	90-91	91-92
Masters	65	54	62	59	37
Doctoral	169	179	158	164	164
TOTAL	**234**	**233**	**220**	**223**	**201**

The total for 1991-92 includes 75 foreign students, 44 female students, and 12 minority students (not including Asian Americans). Graduate admissions data suggest that graduate enrollment will remain in the low 200's for the next several years.

David H. Koch School of Chemical Engineering Practice

This year 28 students participated in the Practice School program at two stations, Dow Chemical in Midland, Michigan and Merck Manufacturing Division in West Point, Pennsylvania. Our first year at Merck has, by all accounts, been a successful one, and the station has provided the important topical focus on biotechnology required by our students. The Midland Station continues to be strong, providing students with exposure to a range of different problems and technologies. Directors and Assistant Directors for the

stations were: Midland Station - Professor Paul Webley and Mr. Aleksander Franz; and Merck Station - Prof. Keith Bailey and Messrs. Ganesh Venkataraman (summer), Paul Nealey (fall) and Ulrich Holeschovsky (spring). As of this summer, Professor Paul Webley has resigned his position, and has been replaced by Professor Barry Johnston. Professors Alan Hatton and Jeffrey Feerer continued to direct the Practice School from Cambridge; as of this summer, however, Professor Feerer will no longer be at MIT.

The 75th Anniversary of the founding of the Practice School was celebrated in October with a mini-symposium titled "The Practice School: 75 Years and Beyond," followed by a Banquet and Dance at the Boston Museum of Science. More than 200 people attended the symposium, with representatives from the Class of '24 up to the present day. The banquet was also well attended, with more than 300 participants. Mr. John Mattill, former Editor-in-Chief of *Technology Review*, completed the commissioned history of the Practice School, appropriately titled *The Flagship*, during the spring. This book has received critical acclaim from our alumni/ae.

FACULTY NOTES

Robert C. Armstrong was elected Vice President of the Society of Rheology. He was invited lecturer at the European Economic Community sponsored conference on "Dynamics of Polymeric Liquids" held in Capri, Italy in September and will be a plenary speaker for the XI International Congress on Rheology in Brussels in August.

Professor Robert A. Brown was awarded the Distinguished Graduate Award from the School of Engineering at the University of Texas at Austin this spring. He also was Centennial Lecturer in the Department of Chemical Engineering at the University of Texas in the fall of 1991. Professor Brown has been active in professional service: he served on the Program Committee of the International Conference on Crystal Growth X which was held in San Diego this August and was named an advisory editor of the AIChE Journal. In March 1992, he was an invited speaker at the NATO Meeting on Interactive Dynamics in Convection and Solidification in Chamonix, France.

Professor Linda G. Cima organized a 3-day international symposium on Tissue-Inducing Biomaterials at the Fall 1991 meeting of the Materials Research Society in Boston and published the symposium proceedings. She was the recipient of a 1991 Presidential Young Investigator Award from the National Science Foundation, and was a keynote speaker at the International Symposium on Surface Properties of Biomaterials in Manchester, England, in May 1992. Professor Cima joined the editorial board of the journal *Cell Transplantation* in January 1992, and continues to hold the Doherty Chair in Ocean Engineering.

Professor Charles L. Cooney was elected a Founding Fellow of the American Institute for Medical and Biological Engineering in 1992, and continues his participation in a National Research Council Panel on Bioprocess Engineering. Professor Cooney continues to serve on the Board of the MIT Community Service Fund.

Professor T. Alan Hatton was elected a Founding Fellow of the American Institute of Medical and Biological Engineering. He also spent six weeks in Japan doing research and giving a series of lectures as a Research Fellow of the Japan Society for the Promotion of Science; one of these talks was a Plenary Lecture at a Workshop on Reversed Micelles in Kyoto. He organized a successful mini-symposium on "The Practice School: 75 Years and Beyond" followed by a Banquet and Dance at the Boston Museum of Science.

Professor Robert S. Langer was elected to both the National Academy of Engineering and the National Academy of Science in 1992. Professor Langer also received the 1992 American Chemical Society Award for Applied Polymer Science, the Charles M.A. Shrine Award in Materials Science and Engineering from the AIChE, and the Organon-Teknika Award from the International Society for Artificial Internal Organs in 1991. Professor Langer was selected as the Miles Distinguished Lecturer at the University of Pittsburgh in 1992, the Kelly Lecturer at Purdue University in 1992, the Ashton-Cary Lecturer at the Georgia Institute of Technology in 1991, the Reigelman Lecturer at the University of California at San Francisco in 1991, and the Sandoz-Dorsey Lecturer at the Ohio State University in 1991.

Professor Edward W. Merrill was an invited lecturer at the American Chemical Society Meeting in August 1991; at the Institut Charles Sadron Centre de Recherche sur les Macromolecules in Strasburg, France, in March 1992; at the Laboratory for Polymer Chemistry of the University of Bordeaux, France, in March 1992; and at the spring meeting of the Materials Research Society held in San Francisco in April 1992. Professor Merrill was elected a Founding Fellow of the American Institute for Medical and Biological Engineering in March 1992.

Professor George Stephanopoulos was appointed the Arthur D. Little Professor of Chemical Engineering in 1992. He was a distinguished lecturer in the Merck sponsored series at Rutgers University and in the Department of Chemical Engineering and Applied Chemistry at the University of Toronto. Professor Stephanopoulos was chair of the International Programming Committee of the IFAC Symposium, "On-Line Supervision and Fault Diagnosis of Chemical Plants," and was awarded the Best Paper Award in the 1991 American Control Conference.

Professor Jefferson W. Tester provided testimony to the U.S. Congress Energy and Environment Subcommittee on Hot Dry Rock geothermal energy and advanced drilling and mining technologies in January 1992, and was the invited plenary speaker to the Conference on Hot Dry Rock and Other Renewable Technologies for the 21st Century sponsored by the Center for Resource Management in Santa Fe in December 1991. Professor Tester serves on the National Research Council Committee on Industrial Waste Minimization and Utilization, and he received the outstanding paper presentation award of the Society of Automotive Engineers on a paper coauthored with Fred Armellini on "Salt separation during supercritical water oxidation of human metabolic wastes," at the 20th Intersociety Conference on Environmental Systems.

Professor Daniel I.C. Wang presented a number of plenary and invited lectures during 1991-92, including the Frank N. Nelson Distinguished Lecture Series in Molecular Biology, Biotechnology, and Medicine, Montana State University (1992); the plenary lecture of the Asia-Pacific Biochemical Engineering Conference, Yokohama, Japan (1992); the opening lecture, Cell Culture Engineering conference, Palm Coast, Florida (1992); and the plenary lecture, International Congress on Computer Applications in Fermentation Technology, Keystone, CO (1992). He also chaired the Japan Technology Evaluation Center's committee to assess the research and development of the bioprocess engineering activities in Japan (1991-92), and was chairman of the 9th International Biotechnology Symposium in Crystal City, Virginia (1992). Professor Wang was a member of the National Research Council's Bioprocess Engineering Committee to define the research needs in the U.S.A. (1991-92), and is chairman of the Temporary Peer Committee on Biotechnology for the National Academy of Engineering. He was elected a Founding Fellow of the American Institute for Medical and Biological Engineering in March 1992, and was awarded the David Perlman Memorial Lecture Award of the American Chemical Society in 1991.

RESEARCH HIGHLIGHTS

Complex Fluids

Understanding the structure of surfaces of oligimeric and polymeric liquids is important to the science of adhesion. Professor Jonathan G. Harris has recently completed a series of simulations of the liquid-vapor interface of the pure hydrocarbons decane and eicosane (a 20 carbon chain). The simulations predict the detailed surface structure as well as the surface tension of the hydrocarbons. Further work is planned to study the relationship between molecular structures and surface structure.

Professor Harris' group is also carrying out simulations of hydrocarbon films between two structured surfaces to understand how branching in the hydrocarbon films influences the liquid structure. It is believed that branching of the chains can disrupt the layering of straight chain alkanes against a wall.

Another part of the complex fluids research deals with the statistical mechanics of supercritical fluid solutions. Supercritical fluids have been proposed as a solvent and medium for the destruction of toxic wastes and the synthesis of new pharmaceuticals. Molecular theory and simulation are being used to understand the mechanisms through which solvation in the supercritical solvent influences chemical reactions.

Fullerenes Synthesis in Flames

Research in the department has shown that the recently discovered hollow ball-shaped molecules known as fullerenes, now the focus of intense research around the world, can be produced in flames. Fullerenes are composed of carbon atoms arranged in closed-cage structures resembling the geodesic domes designed by Buckminster Fuller, after whom the molecules were named. The two best known fullerenes are C_{60}, shaped like a soccer ball and called buckminsterfullerene, and C_{70}, which is elongated like a rugby ball. Fullerenes, like diamond and graphite, are allotropes of carbon. Potential applications for fullerenes include superconductors, lubricants, catalysts, high energy fuels, polymers, and biomaterials.

Fullerenes were first detected in 1985, in carbon vapor from laser vaporization of graphite, and produced in macroscopic quantities in 1990 by graphite vaporization with resistive heating. In 1991, Professor Jack B. Howard and his students found that fullerenes can be produced in large quantities under controlled conditions in benzene/oxygen flames.

The combustion method offers not only a method for large-scale fullerenes production, but an ability to control the relative amounts of C_{60} and C_{70} by adjustment of flame temperature, pressure, and fuel/oxygen ratio. Also, a range of fullerenes including some with metastable structures of interest as reactants can be produced in flames. The chemistry of fullerenes formation in flames is being studied to provide a basis for the design and operation of fullerene synthesis reactors, and to search for new fullerene types.

Biodegradable Polymers

Recent industrial patents have indicated the feasibility of processing pure starch as well as starch blends by traditional thermoplastic means. Inasmuch as starch is 100 percent biodegradable, the ability to substitute starch for certain current commodity polymers promises to revolutionize the polymer and polymer processing industries. Key to the replacement of commodity plastics with starch and starch blends is the ability process thermoplastic starch pellets in standard, commercial equipment while achieving adequate stability and acceptable mechanical and environmental properties. Because of the very short time that has elapsed since the

discovery that starch could be thermoplastically processed, little is known about the range of structures and properties that can be obtained with starch (and its blends), the rheological properties of the molten material that affect its processing, and the interaction between the processing and the product properties.

A new research program under the direction of Professors Robert C. Armstrong and Edward W. Merrill in collaboration with Professor Edwin L. Thomas of Materials Science and Engineering is investigating the processing of thermoplastic starch by focusing on fiber spinning as a target application. This program emphasizes the need for close interaction among three subproblems in order to produce a successful product: these are starch chemistry (Professor Merrill), product structure/ properties (Professor Thomas), and rheology/processing (Professor Armstrong). By focusing these activities around the fiber research vehicle, this joint program provides a model to be copied by industry for research and development on other products and processes of commercial interest.

Various starch esters, ranging from starch triacetate to starch tributyrate have been synthesized by Professor Merrill's group from high amylose starch. Physical property studies of films cast from these polymers indicate that the tributyrates are preferable from a processing point of view, both in terms of product properties and processibility. To demonstrate this, fibers have been spun successfully from starch tributyrate and morphological and physical property characterization of studies are now underway.

DEPARTMENTAL AWARDS

The Chemical Engineering Department's Awards Program was held on Wednesday, May 13, 1992 in the Edwin R. Gilliland Auditorium. Professor Brown presided over the ceremonies at which the following awards were made:

The Amoco Foundation Undergraduate Scholarships in Chemical Engineering for 1991/92 to Cora M. Dancy (junior from Merrimack, NH), Claire L. Hypolite (junior from Colorado Springs, CO), and Michael Yu (junior from Cherry Hill, NJ) were acknowledged. The Dunbar L. Shanklin Undergraduate Chemical Engineering Scholarships for 1991/92 to Natalya Eliashberg (junior from Palo Alto, CA) and Joshua A. Levinson (junior from Endwell, NY) were acknowledged. The Dow Outstanding Junior Award recipient was Cherry P. Wongtrakool (junior from Warren, OH) for a balanced record of achievement in academics and campus professional and social organizations, as well as work experience.

The American Institute of Chemical Engineers Annual Chapter Scholarship Award was given to Natalya Eliashberg , a member of the AIChE student chapter, for highest scholastic performance through the first two years in Chemical Engineering. The New England Chapter of the American Institute of Chemists (AIC), annually honors "outstanding seniors in recognition of potential advancement of the chemical professions on the basis of the student's demonstrated record of leadership, ability, character, and scholastic achievement." This year's recipient was George Alexopoulos (senior from Athens, Greece). The Robert T. Haslam Cup was awarded to Rachel M. Huggins (senior from St. Louis, MO) for outstanding professional promise in Chemical Engineering. The Roger de Friez Hunneman Prize, the oldest prize in the department and first awarded in 1927, was presented to Isy Goldwasser (senior from North Miami Beach) in recognition of outstanding scholarship and research.

The newly initiated members of Tau Beta Pi, the Engineering Honorary Fraternity for excellence in academic studies, were acknowledged: Robert Bingel (senior from Lyon Mountain, NY), Taweesak Bunluesin (senior from Samutprakarn, Thailand), Jennifer Chan (senior from Lexington, KY), Isy Goldwasser, Rachel Huggins, Hui-lin Lai (senior from Singapore), Tina Srivastava (senior from Singapore), Michelle Toyofuku (senior from Aiea, HI), Gheorgios Varsamis (senior from Ekali-Athens, Greece), Amy Whiteman (senior from Boise, ID), Natalya Eliashberg, Claire Hypolite, Victor Silhy (junior from El Salvador), Michael Yu; along with students previously inducted into Tau Beta Pi: George Alexopoulos, Joshua Levinson, and David Rich (senior from Plainview, NY). In addition, Professor Brown announced that Tina Srivistava had been awarded the Institute's Randolph G. Wei UROP Award for her research in protein partitioning, which led to a paper on macromolecules.

The Outstanding Teaching Assistant Award was presented to Mark Prausnitz (graduate student from Berkeley, CA) for excellence in teaching in an undergraduate subject. Awards for second place were given to Radha Nayak (graduate student from Bombay, India) and Gokaraju Raju (graduate student from Bangalore, India). The Chemical Engineering Department Special Service Awards were given to Edward P. Browne (graduate student from Dublin, Ireland), Todd R. Salamon (graduate student from Bristol, CT), Suresh Ramalingam (graduate student from Madras, India), and Jean Condon (senior from Medford, MA), for their unselfish contributions to the success of departmental activities. The Chemical Engineering "Rock" Award for outstanding athletics, voted on by the graduate students in the department, went to Lars H. Genesier (graduate student from Haddonfield, NJ). The Department's Outstanding Employee Award was given to Patricia McGinnis, an Administrative Secretary, for exceptional service to the department and its students. The Outstanding Faculty Award (from the graduate students) was presented this year to Professor Edward W. Merrill. The Chemical Engineering Outstanding Faculty Award (from the undergraduate students) was presented to Professor Jeffrey L. Feerer.

ROBERT A. BROWN

Department of Civil and Environmental Engineering

INTRODUCTION

As of July 1, 1992 the Department of Civil Engineering is officially renamed the Department of Civil and Environmental Engineering. In addition the department has taken a major step in defining its future direction in all of its specialty areas, Water Resources and Environmental Engineering, Transportation, Constructed Facilities, Construction Management, toward education and research on environmental concerns.

Environmental engineering is an ABET-accredited discipline aimed at protecting the public and the environment from pollutants. About half of the departmental faculty fall more accurately under the category of Environmental Engineering rather than Civil. Their research covers work in fate and transfer of pollutants in water, ground water and soil, environmental measurement and modeling, aquatic biology and microbiology, aquatic chemistry, hydraulics and fluid mechanics of natural systems, coastal engineering and sediment transport, the containment of wastes in the ground, the environmental impacts of construction, assessment of underground pollution, and on interactions between transportation options and the environment.

In research and education the department reaches out to activities throughout the Institute. The department is heavily involved in the Center for Global Change Science, the Center for Environmental Health Sciences, the Program in Environmental Engineering Education and Research, the Hazardous Substances Management Program, the Program in Business, Technology and the Environment of the Center for Technology, Policy and Industrial Development, the MIT Woods Hole Joint Program, and the MIT Sea Grant College Program.

In the traditional civil engineering areas, the Center for Construction Research and Education ran a large conference, formed a major Consortium in Construction and the Global Environment, and provides a graduate educational program. Through the Center for Transportation Systems the department is evolving new research and teaching in congestion- and pollution-related problems of large scale transportation systems. The department teaches in the Chemicals in the Environment graduate sequence, in the environmental literacy service subjects for undergraduates, in new subjects in Technology and the Environment, and in a number of Independent Activities Period (IAP) subjects during January.

All these activities in the environmental side of large scale construction, infrastructure development and the protection of human life and the environment fit well with the focus of our traditional program in civil engineering. It has a strong constructed facilities, construction materials, construction management, engineering design, transportation and logistics and civil engineering systems focus and continues its world leadership as it has in the 131 years since the founding of MIT.

In another major event for the Department, Rafael L. Bras, William E. Leonard Professor of Engineering, Associate Director of the Center for Global Change Science and a prominent member of the department's Water Resources and Environmental Engineering group, will become Head of the Department of Civil and Environmental Engineering on August 1, 1992. David H. Marks, who has served for the past seven years in the role of department head will return to teaching and research as Director of the new School-wide Program for Environmental Engineering Education and Research (PEEER).

Undergraduate Education

The Department of Civil and Environmental Engineering now has two undergraduate degree programs: Course I-C Civil Engineering and Course I-E Environmental Engineering Science. Each teach about half of our total undergraduates in the

Department. The new course, I-E, now has close to seventy students and has grown explosively to account for more than half of all Course 1 undergraduates. About one-third of the three-hundred graduate students are also studying for environmental careers. In Course I-C a redirection of the curriculum has been made towards the use of innovative materials and the integration of analysis and construction in the design process. In particular the department seeks to broaden civil engineering education beyond its traditional emphasis on engineering science by the integration of design throughout the undergraduate curriculum. This is being done by integration of design in the core engineering science subjects and offering new required subjects including a capstone subject in Engineering Design. We are also working to broaden engineering education to deal with contextual and ethical issues through interactive case studies and in required design projects by encouraging creative uses of interactive computer programs. The department focus is on the design of large-scale constructed systems thus defining design in the broadest terms. This encompasses the entire development life cycle-planning, system design, construction and maintenance, the generic principles and methods used to design and control quality, development schedule, cost and flexibility, and the impact of how people, processes and information are organized and managed during the entire development process.

Course I-E which is more recent (formed officially in 1990) is also working to put more design into its curriculum and will be experimenting with an environmental engineering clinic in which students actually work on a problem related to practice during a senior capping experience. Revisions in the undergraduate subjects in biology, chemistry, engineering and economics are also being made to include more design examples. We are pleased with the support of the program given by the Departments of Mechanical Engineering, Chemical Engineering, Toxicology and Urban Planning through the provision of subjects for students in this program.

Graduate Program
This section has been incorporated into the following individual Division listings.

Constructed Facilities Division (CFD)
CFD faculty have developed and implemented a new, highly innovative approach to integrating design into the undergraduate engineering educational program. They are playing a major role in the Engineering Coalition of Schools for Excellence in Education and Leadership (ECSEL) program, a multi-university effort funded by the National Science Foundation to improve the design aspect of engineering education. The MIT approach is expected to serve as the catalyst for a major restructuring of civil engineering design education in the United States.

Advancing the scientific knowledge of construction materials and developing the information technology required to improve the engineering problem solving process are the two main research thrusts of the Division. A significant technical accomplishment in the materials area was the conceptualization and successful manufacture of a new type of structural reinforcing rod composed of a mixture of epoxy, glass, and carbon fibers. This element will solve the durability problem, a major issue for concrete construction. Advancements that have narrowed the knowledge gap were also achieved for fiber reinforced composite systems, such as reinforced earth and concrete structures. Divisional faculty working within the Intelligent Engineering Systems Laboratory (IESL) are pioneering the application of object-oriented technology to large scale engineering problems. Unique approaches to data structure modeling, design of distributed systems, and wavelet-based representation and processing were developed during the past year.

Transportation Systems Division (TSD)
TSD during the past year advanced in the development of its educational and research programs. TSD faculty, with Prof. Nigel Wilson in a leadership role, participated in a re-examination of the Master of Science in Transportation (MST) degree. This re-examination led to a redefinition of the core requirements for

MST with two new subjects to be taught by Prof. David Bernstein and the newly recruited Prof. Cynthia Barnhart, joining us from the faculty of Georgia Tech.

TSD faculty participated in the development of an MIT Intelligent Vehicle Highway System (IVHS) research program with Prof. Moshe Ben-Akiva leading this effort and with Profs. David Bernstein, Haris Koutsopoulos and Mr. Tom Humphrey as active participants. Also, the program is coordinated with Lincoln Lab. Prof. Joseph Sussman, on sabbatical, participated in the development of the national IVHS program.

TSD had a successful year and continues to play a leadership role in transportation education and research at MIT.

Water Resources and Environmental Engineering Division (WREED)
The $2 million renovation of the Parsons Laboratory (aided by a $700,000 grant from NSF) was completed in October 1991, resulting in much improved facilities for the division's teaching and research activities. During 1991-92, the division undertook two major educational initiatives: It began the processes of seeking ABET accreditation for the 1-E bachelor's program and revising the graduate environmental offerings.

Intelligent Engineering Systems Laboratory (IESL)
IESL is a research and academic group within the department. IESL's research mission is to advance and develop information technology for the problems of large scale engineering systems. The program centers on four key areas: the computer representation of engineering data and processes, the understanding of design processes and division of labor between human and machine in design, the computer understanding of maps and engineering drawings, and the use of distributed computing in sharing engineering information. The group has particular expertise in the application of object oriented systems to information technology and in the development of novel representation techniques for data and knowledge representation.

The laboratory maintains close links with industry through its sponsors who provide an average of six permanent researchers based on campus. Projects within the group concentrate on the development of fundamental research ideas which are implemented in a prototypical industrial environment. Two of the sponsoring companies have recently signed a cooperative agreement to develop a large scale version of an IESL design system within their company.

Research plans are proposed by the faculty and are reviewed by a joint academic/industry advisory board. The industrial consortium currently funds $500,000 per annum and supports six faculty members and approximately fourteen graduate students. The laboratory maintains a modern computing facility of some twenty workstations, image processing equipment and video authoring capabilities and provides computing support to other areas of the department; such as the CFD. IESL research links the department to the Media Laboratory, Mechanical Engineering, the Center for Transportation Studies, and the Sloan School of Management.

IESL maintains an academic program in computer aided engineering at the Master's and Doctoral level.

Center for Construction Research and Education (CCRE)
During the past year CCRE continued its accomplishments as one of the Nation's leading graduate programs in construction engineering and management. During the year, twenty-seven CCRE students completed advanced degrees including: twenty-two masters, one engineer, and four doctoral. Enrollment in the center continues at the level of thirty-five master's degree and fifteen doctoral degree candidates. Significant progress was also made in the center's research and industry interaction programs. Industry membership in the Consortium on the Construction

Industry and Global Environment was expanded from one to three companies, and sine the Consortium was established in January 1991, eight students completed significant theses in the areas of environmental markets, technologies and business strategies. In October, the center presented a symposium on Global Environment and the Construction Industry which brought together over 180 experts from industry, academia, government, and the legal profession to examine current issues, challenges, and trends affecting the construction industry's growing role in environmental preservation and remediation. With respect to industry interaction, the center commemorated its 10th Anniversary with a second symposium Construction Industry in the Northeast: Opportunities for the 21st Century. This symposium was an overwhelming success drawing over two-hundred top industry executives as speakers and participants from seventeen states, and from all facets of the engineering and construction industry and supporting services. The symposium has established a solid foundation for the development of expanded industry interaction activities in support of the center's second decade.

Department Administration
Department Head, Professor David H. Marks
Chairman of the Undergraduate Program, Professor Daniele Veneziano
UROP Coordinator, Professor Harold Hemond
IAP Coordinator, Professor Eduardo Kausel
Chairman of the Graduate Program, Professor Ole Madsen
Admissions Officer, Professor Eduardo Kausel
Coordinator of the Student Chapter of ASCE, Professor Andrew Whittle
Coordinator, Chi-Epsilon, Civil Engineering Honorary Dr. Jack Germaine
Head, WREED, Professor Francois Morel
Head, CFD, Professor Jerome Connor
Head, TSD, Professor Yosef Sheffi
Head, CCRE, Professor Fred Moavenzadeh
Head, IESL, Professor Steven Lerman
Engineering Internship Program Coordinator, Professor Oral Buyukozturk
Director, Academic Programs Office, Ms. Cynthia Stewart

Institute Service Roles
The department continues to play an important role in the leadership of the Institute. Faculty members serving in such roles are: Professor Daniel Roos, Director of the Center for Technology, Policy and Industrial Development, Professor Steven Lerman, Director of the Center for Educational Computing Initiatives, Professor Richard de Neufville, Chairman of the Technology and Policy Program, Professor Frank Perkins, Dean of the Graduate School, Professor Yosef Sheffi, 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 Philip Gschwend, Head of the Joint MIT/Woods Hole Program in Chemical Oceanography, Professor Rafael Bras, Associate Director of the Center for Global Change Science, and Professor David H. Marks, Director of the Program in Environmental Engineering Education and Research (PEER).

Faculty and Staff Changes
One new faculty member started this year: Assistant Professor Dara Entekhabi (WREED) is a Hydrologist and will be working in the area of hydrologic implications of global climate modeling.

Professors on leave Professors Ole Madsen and Dennis McLaughlin.

Promotions
To Associate Professor (without tenure), Prof. Duvvuru Sriram
To Senior Research Engineer, Dr. Eric E. Adams

Department Statistics
Number of Faculty: 38, June 1992. Number of Undergraduates: 125, Number of Graduate students: 263, department research expenditures for AY 90-91: $8,507,000.

Faculty and Staff

Dr. E. Eric Adams, Senior Research Engineer (WREED), was recently appointed Associate Director for Research of the MIT Sea Grant College Program and has served this past year on the steering committee of the regional association for research on the Gulf of Maine. Starting in September he will direct the department's new Environmental Engineering Clinic, part of the undergraduate Course I-E curriculum in which students work as interns for local consulting firms or regulatory agencies on environmental projects of current interest. He continues his research on Boston Harbor, initiating a new two-year study involving fluorescent tracer studies and numerical modeling of impacts from combined sewer overflows.

Professor Moshe Ben-Akiva (TSD) has overseen the development of MIT's IVHS program of which he currently serves as Director. He and the research program received extensive publicity during the past year, including a featured article in the *New York Times*, and were the subject of the cover article in the July 1992 issue of *Technology Review*. In recognition of his contributions to the field of transportation research, he will be awarded the Doctor Honoris Causa Degree on July 1, 1992 by the Universite Lumiere Lyon, Lyon, France.

Professor David Bernstein (TSD) who recently received a Mitsui Career Development Chair, is playing a major role in the MIT IVHS research program. His current activities focus on the development of dynamic network equilibrium models for the evaluation of demand-oriented strategies for mitigating congestion and its economic and environmental impacts (e.g., road pricing, parking policies). In addition, he is devoting some of his time to research into data management and visualization techniques for IVHS. Papers on these topics will be appearing shortly in *Operations Research* and the *Proceedings of the 1992 Geographic Information Systems in Transportation Symposium.*

Professor Rafael Bras (WREED) after eight years stepped down as Director of the Ralph M. Parsons Laboratory and Head of WREED. He continued as Associate Director of the Center for Global Change Science in which capacity he convened and hosted an international symposium at MIT entitled The World at Risk: Natural Hazards and Climate Change. He is presently editing the Proceedings of that meeting to be published by the American Institute of Physics in book form. Prof. Bras is a member of the Board of Atmospheric Sciences and Climate of NRS, a member of NASA's Tropical Rainfall Measuring Mission Science Team, a member of NASA's Earth Science and Applications Division Advisory Board, advisory panel of NSF's Geosciences - Continental Hydrology Program, the Science Steering Committee of the GEWEX Continental Scale International Program, and advisor to the University of Puerto Rico's Hemispherical Cooperation Program (COHEMIS) and Minority Research Center of Excellence (MRCE) Program. Prof. Bras has also been reappointed for a new term as Chairman of the Budget and Finance Committee of the American Geophysical Union. This year Prof. Bras received a joint appointment as Prof. of Earth, Atmospheric and Planetary Sciences. The University of Perugia, Italy, awarded him an honorary degree (honoris causa laurea) for his work in hydrology.

Professor Oral Buyukozturk (CFD) received funding from Army Waterways Experiment Station for new research directions he has developed on non-destructive evaluation of concrete using microwave techniques, jointly conducted with the Department of Electrical Engineering and Computer Sciences and Lincoln Laboratory. Other major research activities included High Performance Materials funded by NSF and Fatigue Life Prediction of Railway Bridges funded by CSX Transportation. He has participated as a member of the US team in an international workshop on Preservation of Domed Historic Master Works sponsored by NSF in May 1992.

Professor Sallie W. Chisholm (WREED) was the recipient of the 1991 Rosentiel Award in Oceanographic Sciences and became a Fellow of the American Academy of Arts and Sciences. She continues as Director of the MIT/Woods Hole Joint Program in Oceanography and Oceanographic Engineering and is a member of the MIT Council on the Global Environment.

Professor Jerome J. Connor (CFD) served as Chairman of a special committee formed by the National Science Foundation to define the mission and organizational structure for a National Institute for Constructed Systems. This Institute is an important element of the new NSF initiative in Civil Infrastructure Systems. He has developed a new approach to structural design that represents a major advancement over the conventional approach. This methodology is currently being applied to tall buildings by Japanese Architectural/Engineering firms in collaboration with Nippon Steel.

Professor Peter Eagleson (WREED) received multiple honors during the year, the Sterling B. Hendricks Memorial Lectureship of the Agricultural Research Service, the International Hydrology Prize of the International Association of Hydrological Sciences, and the Thomas B. Nolan Distinguished Lectureship of the U.S. Geological Survey. In addition, MIT named him the James R. Killian Jr. Faculty Achievement Awardee for 1992-93.

Professor Herbert Einstein (CFD) continues development of computer-based educational modules in the context of vertical and horizontal integration of design into the curriculum. He presented a paper on fracture coalescence representing a major advance and had collaborative effort with five universities to develop a new tunneling system. Prof. Einstein has worldwide involvement in major tunnel projects.

Professor Lynn Gelhar (WREED) is completing final editing on an important new book entitled Stochastic Subsurface Hydrology which is scheduled for release in 1992. His research, focusing on field-scale contaminant transport in ground water, includes a new initiative, guided jointly with Prof. John Southard (EAPS), using geologic information to characterize aquifer heterogeneity on Cape Cod. He has also initiated work, sponsored by the U.S. Nuclear Regulatory, which explores hydrologic aspects of performance assessment modeling for low-level radioactive wastes disposals facilities.

Dr. John T. Germaine (CFD) has continued his important MIT roles including the supervision of the ASCE concrete canoe project and Freshmen advising. He has had substantial impact on the Geotechnical profession through involvement with ASTM. This year he was appointed to the D18 executive committee and the editorial board of the Geotechnical Testing Journal.

Professor Lorna Gibson (CFD) won a National Science Foundation Faculty Award for Women which she is using to pursue two new research areas: biomechanics and bone mechanics. Over the past year she has increased her collaboration with the Orthopedic Biomechanics Laboratory at the Beth Israel Hospital/Harvard Medical School and is now co-supervising projects on osteoporosis induced fatigue failure of bone, damage mechanics of bone and the design of protective hip pads for elderly patients at high risk of hip fracture. Her work on modeling the mechanical behavior of cellular materials continues. This year, in collaboration with Dr. Tim Tonyan, a former student, she has applied for a patent for an improved micro-structural design for cellular materials.

Professor Harry Hemond's (WREED) 1.725 Chemicals in the Environment: Fate and Transport enrolled a record size of 32 students, all completing the subject. He continued work on a textbook for 1.725 to be published by Academic Press. He was appointed Associate Director of the Center for Environmental Health Sciences (CEHS) and through this has participated in a successful proposal which brings $750k/year to the Parsons Laboratory. He continued work on the Aberjona Project, participated in general meetings with local citizens and officials. He found evidence for two major episodes of metal contamination on the watershed, plus evidence of mutagenicity to human cells in lake sediments on the watershed.

Mr. Thomas F. Humphrey (CTS) is the Director of the Region One (New England) University Transportation Center (UTC) located at MIT. This federally funded

program provides $1 million annually to MIT, which must be matched equally with non-federal funds. The fourth year program, covering September 1, 1991 - December 31, 1992 provided twelve fellowships for MST candidates. The research program sponsored by the Region One UTC is focused on IVHS, Transit and Public Policy issues. Six MIT faculty plus eight graduate students were funded to undertake five research projects. Mr. Humphrey formed a New England Consortium of Toll Agencies to develop a compatible electronic toll collection system throughout New England. A formal interagency agreement established this multi-state program, a first such event in the Region. He was honored by his peers by being selected as the Outstanding Engineer of the Year (1990-91) by the New England Section of the Institute of Transportation Engineers. He was also elected to be the President of the Council of University Transportation Centers (CUTC), a national organization of about forty universities.

Professor Eduardo Kausel (CFD) was Graduate Admissions Officer, Graduate Officer, and IAP representative. He was also advisor to some nineteen undergraduate and graduate students, and supervised three master's theses and two doctoral dissertations (all of which completed). Prof. Kausel was involved with the ASCE Dynamics Committee, reviewed many papers and research proposals for various organizations, had three papers to be published in prestigious journals and two in conference proceedings. During his sabbatical in the Fall he will work in Spain at CEDEX, the Center for Experimental Studies.

Professor Lee Krumholz (WREED) taught two new courses, both at the graduate level, Environmental Microbiology in the fall and a specialized course Microbial Transformations in the Spring dealing with current research in microbial degradation and transformation processes in the environment. He is working with students on developing experimental strategies to predict degradation of Toluene, an industrial solvent in a local river in the Aberjona Watershed, characterizing the microbial population involved in the degradation of this solvent and understanding the extent of the mechanisms of the microbial processes that are involved in environmental arsenic transformation.

Professor Charles Ladd (CFD) has been invited to serve as a member of the Geotechnical Board of the National Research Council for a two year term starting in July 1992. The Board was established in 1987 to provide the NRC with a unified capability to address geotechnical engineering and science issues of national scope and consists of 13 members drawn from government, industry and academia. He is also working on the redesign and construction of a large offshore breakwater on a soft clay deposit for a shipping terminal in Brazil which had a massive foundation failure in 1989.

Professor Steven Lerman (TSD) holds the Class of 1922 Distinguished Professorship. He directs the Center for Educational Computing Initiatives, an MIT-side research center involved in the development and application of computing technologies for education. Among other activities, Prof. Lerman directs a large project within the center that is developing an authoring system for multimedia applications. He has completed an undergraduate textbook on computing methods entitled "Problem Solving and Computation for Scientists and Engineers: An Introduction Using C" which will be published by Prentice-Hall in late 1992. The manuscript of the book is used in the teaching of Subject 1.00 in the Civil Engineering Department.

Professor Robert Logcher (CFD) has been appointed as a Visiting Professor at the Universidad Gabriela Mistral in Santiago, Chile, where he has lectured on project management and computer systems. He presented a seminar on the Role of Computers in Design/Construction Integration to the Architectural Institute of Japan in Tokyo in June.

Professor Ole S. Madsen (WREED) was on sabbatical leave for 1991-92. He spent part of the year at Virginia Institute of Marine Science participating in a joint research project on field measurements of bottom boundary layer processes in inner-shelf waters as well as offering a short course on the same topic. He also

spent six weeks visiting Kyoto, Osaka, and Tokyo Universities as a Fellow of the Japan Society for the Promotion of Science.

Mr. Carl Martland, Senior Research Associate, (TSD) at the Transportation Research Forum's Annual Meeting in New Orleans, became only the second recipient of the Herbert O. Whitten Award for outstanding lifetime service to the Transportation Research Forum (TRF). He also co-authored the paper that won TRF's $2,500 Outstanding Paper Award along with the $1,500 Conrail Award. This was the third straight year that he has won the Conrail Award, which is given for the best paper on railroads presented to the TRF.

Professor Chiang C. Mei (WREED) won the 1992 John. G. Moffat-Frank E. Nichols Harbor and Coastal Engineering Award of the American Society of Civil Engineers. The award will be presented at the ASCE Conference in New York in September 1992. He is currently working on new research areas in dispersion of suspended sediments in waves and randomness on the sea surface. He was the keynote speaker at an ASCE Engineering Mechanics Specialty Conference at Texas A&M in May 1992

Professor Francois Morel (WREED) supervised the $2 million renovation of the Ralph M. Parsons Laboratory whose Directorship he took over from Rafael L. Bras in September. Besides his usual teaching and research duties he co-edited (with S. W. Chisholm) a special issue of *Limnology & Oceanography* dealing with oceanic primary production -- an important topic in the context of the global CO2 cycle. He also completed (with J. Hering of UCLA) a new edition of his teaching text: *Principles and Applications of Aquatic Chemistry.*

Dr. S. Shyam-Sunder (CFD) was awarded the 1991 Walter L. Huber Research Prize by the American Society of Civil Engineers. He has initiated a major new collaborative research project on "Physically-Based Constitutive Modeling of Ice" with the help of a quarter-million dollar annual grant from the Office of Naval Research as part of its five-year Accelerated Research Initiative in Sea Ice Mechanics. He was also appointed to a six-member independent panel by the Naval Sea Systems Command to evaluate the U.S. Navy's Submarine Arctic Structures Program and to the National Academy of Sciences/National Research Council Committee on Cooperation with the USSR (Russia) on Ice Mechanics. In addition to his continuing research in ice mechanics, he is actively involved in the Department's research and educational initiative in the area of Engineering Design. The NSF-sponsored ECSEL program in funding his work on the Integration of Design in the Civil Engineering Curriculum through both the establishment of a design laboratory in civil engineering and an ECSEL-wide collaboration effort led by him.

Professor Duvvuru Sriram (CFD) in addition to supervising the research activities of the DICE group, has co-authored several journal articles and has finished a three volume edited series entitled *Artificial Intelligence in Design*, which is being published in July. He was a keynote speaker at the ABCDE conference organized as a part of the 150th anniversary of the Technical University of Delft, Netherlands. Prof. Sriram has delivered lectures on his DICE project in India, Netherlands, Belgium, France, and Italy. He was also an invited participant in several workshops on concurrent engineering. He was also invited to become a member of the Advisory Board for the BIKIT organization which is part of the University of Ghent, Belgium. As a recognition of his work on concurrent engineering, he was invited to become a co-editor of the international *Journal Concurrent Engineering: Research and Applications*, to be published by Academic Press.

Professor Joseph M. Sussman (TSD) was named the first Japan Railroad East Professor, a chair endowed by the East Japan Railway Company. He was so honored at the JAPAN RAILROAD East Technoplaza in September 1991 and presented an address entitled "Transportation, New Technology and the Railroads: A Broad Perspective." On sabbatical for this past year, Prof. Sussman served as the first Distinguished University Scholar at IVHS America in Washington, DC. He was a member of the core

group that wrote "A Strategic Plan for Intelligent Vehicle Highway Systems in the United States," as a twenty year plan for a public/private/academic partnership for research, development testing and deployment of IVHS technologies.

Professor William G. Thilly (Toxicology) holds a secondary appointment in Civil Engineering where he continues work with our environmental group. He has led the effort to obtain major new support for departmental faculty via the Super Fund Basic Research Grant. Within the department the fate and transport of hazardous chemicals in the nearby Aberjona River Basin are being studied from dump sites through the streams and ground water to human exposure.

Professor Thanasis Triantafillou (CFD) has been on a year's leave serving in the Greek Army.

Professor Robert Whitman (CFD) is restoring more emphasis on design (i.e., on engineering as opposed to science) into the IC undergraduate curriculum. He has changed 1.30 from a subject in soil mechanics oriented primarily toward analysis to a subject built around four design exercises involving open-ended problems. During the spring he worked with freshmen on a large-scale design exercise concerned with high-speed rail in the Northeast Corridor. Outside MIT his principal efforts have been the Congressional-established Advisory Committee for the National Earthquake Hazards Reduction Program, the Scientific Advisory Committee for the National Center for Earthquake Engineering Research in Buffalo, and the Committee of Experts for raising and reconstruction of the dikes along Lake Maracaibo in Venezuela. He became Honorary Member in the Boston Society of Civil Engineers Chapter of ASCE and received the C. Martin Duke Lifeline Earthquake Engineering Award from ASCE.

Professor John R. Williams (CFD) has pioneered the development of a discrete analysis tool called the Discrete Element Method (DEM) that explicitly models the discontinuous micro structure. This tool is now gaining acceptance within the engineering research community and Prof. Williams is organizing the 2 nd International Conference on Discrete Element Methods, at MIT in March 1993. His contributions to DEM technology include super quadric object representation and multi-level analysis techniques based on wavelet functions. (The approach to engineering analysis has been dominated by continuum mechanics that entirely neglects the "ball bearing" like atomic world, which we know exists at the microscopic level).

Professor Nigel H. M. Wilson (TSD) was on the steering committee for the Second International Conference on Bus Deregulation and Privatization held in Tampere (Finland) where he chaired a series of workshops. His research continues to be focused in two areas both related to urban public transportation. The first topic is the use of real-time information to improve service quality on rail systems. This year he presented papers on this research to Transportation Research Board conferences in Washington DC and Calgary. The second topic is the use of contracted bus service to improve the efficiency of public transport systems. He continues to direct the interdepartmental Master of Science in Transportation degree program which now has a record enrollment of 43 students.

DAVID H. MARKS

This year the department reached consensus about new professional curricula for both electrical engineering and computer science. Current plans call for these curricula to be introduced over the next few years, subject to the necessary Institute approvals. We expect most students to opt for both master's and bachelor's degrees. The bachelor's degrees are expected to continue to be accredited; they have requirements quite similar to those of our current degrees. The requirements for the new master's degrees are more challenging, and will typically take a full-time student five years rather than four. The master's degrees are not expected to be accredited, but because the curricula have been defined so that the requirements for the bachelor's degrees are proper subsets of those for the master's degrees, all master's candidates can automatically receive the corresponding (accredited) bachelor's degree.

During the next year we will work to gain the necessary approvals for the new curricula, and develop the new courses needed. We anticipate having the new curricula apply to students who enter MIT as freshmen in 1993 and later years.

Undergraduate enrollment in the department continues to be large. Clearly both electrical engineering and, especially this year, computer science, are viewed as attractive careers by MIT students.

During the past year we have continued to define a comprehensive research program in modern telecommunications, including the societal impact of advances in communications and the effects of governmental regulation on the development of an appropriate infrastructure.

UNDERGRADUATE PROGRAM

Enrollment of undergraduates averaged 950 in 1990-91, with about 60% in the Electrical Engineering Program and 40% in the Computer Science Program. From the Class of 1994, 350 students were enrolled in Course VI, which was only a few more than the preceding class. About 280 students from the Class of 1995 have so far selected Course VI. The ratio of 6:1 (Electrical Engineering) to 6:3 (Computer Science) students which altered radically last year, from 2:1 to 11:9, has moderated slightly to 42% 6:3's in the Class of 1995. The Class of 1994 continues to have the largest number of Computer Science students in the department's history, with approximately 150 students.

The following prizes and awards were won by our students:

The Ernst A. Guillemin Prizes for the outstanding S.B. theses in Electrical Engineering were awarded to Stephen Y. Hon of Scarborough, Canada (First Prize) and Daniel B. Olster of Los Angeles, CA (Second Prize). Honorable Mentions went to Tanweer Kabir of Mindeff, Brunei, and Whay Sing Lee of Penang, Malaysia.

The David Adler Memorial Thesis Prize for Undergraduate Theses in Electrical Engineering was presented to Sujata Madan of New Delhi, India.

The Charles and Jennifer Johnson Prize for the outstanding undergraduate thesis in Computer Science was presented to Joanna L. Kulik of Ann Arbor, MI.

The William A. Martin Memorial Prize for the best thesis in Computer Science was won by Vijayaraghavan Soundararjan of Williamsport, PA, and by Rajeev J. Surati of Seattle, WA.

The Computer Systems Prize was not awarded this year.

The George C. Newton Prize for the best undergraduate laboratory project was awarded to Christopher A. Cooke of Hinkley, CA, Todd E. Knibbe of Clarkston, MI, and to Karl Sun of Troy, MI.

The Northern Telecom/Bell-Northern Research Inc. Award for the best undergraduate laboratory project was awarded to Mark S. Bower and Derek R. Curd.

The David A. Chanen Writing Award, for the best Computer Science paper used to satisfy the second phase of the Writing Requirement, went to Frank Y. Ho, of Vancouver, Canada.

GRADUATE PROGRAM
In September, 1991, there were 690 graduate students enrolled in the department. Of this number, 183 were newly admitted. About 20 percent of the total were foreign nationals. The department supported 336 Research Assistants and 107 Teaching Assistants. In addition, there were 151 fellowships including 41 National Science Foundation Fellows, 7 Hertz Fellows and 15 Office of Naval Research Fellows. The remaining students had industrial or foreign support or were using their own funds.

During 1991, the department awarded 159 Master of Science degrees, 20 Electrical Engineer degrees and 52 Doctoral degrees.

The department received 1849 applications for the 1991-92 year, a slight increase over 1990. The applications continue to be generally excellent and 299 were admitted for 1992 (February, June and September), of whom approximately 194 are expected to register for next fall.

A number of awards were made to graduate students for excellence in teaching. Jennifer A. Lloyd of Emmaus, PA, received the Carlton E. Tucker Award and Robert A. Shumsky of Belmont, MA, received the Harold L. Hazen Teaching Award. The Frederick C. Hennie III Awards for excellence in teaching were presented to Salman Akhtar of Lahore, Pakistan, and Ruth Schonfeld of Westlake Village, CA. John R. Buck of Cambridge, MA, was promoted to Instructor-G in recognition of his demonstrated teaching abilities and services to the department. Ellen Spertus of Austin, TX, and Michael P. McCue of Cambridge, MA, were recipients of Department Meritorious Service Awards.

VI-A INTERNSHIP PROGRAM (Kevin J. O'Toole)
In June 1992 the Department's VI-A Internship Program celebrated its 75th Anniversary. In conjunction with MIT's Technology Day activities, a symposium was held in Edgerton Hall with speakers including Professor Elwyn R. Berlekamp, Professor Amar G. Bose, Professor Joel Moses, Professor Paul L. Penfield, Jr. and Professor William M. Siebert. Kevin J. O'Toole, Director of the Program, presided. An exhibit showing the progress of the VI-A Program since its inception in 1917 was featured in the Grier Room. Many alumni attended these festivities which culminated in a banquet held at the MIT Museum on Saturday evening.

The program continued its popularity and excellent performance as attested by the 201 sophomores who applied. After the record number of interviews conducted by the company representatives, 81 students were finally accepted.

Due to the current business climate, several of the existing companies did not accept students this year. However, four new companies — Delco Electronics/GM, Hughes, Intel, and Jet Propulsion Laboratory — have joined the Program and we look forward to a long and meaningful association.

In June, 43 VI-A students received advanced degrees having completed all their Company Assignments and Institute degree requirements. There were 27 students who were awarded their Bachelor's degrees and most of them will continue into the graduate phase of the Program.

Many honors and awards continue to be bestowed on VI-A students. At the department's Awards Reception held at the Boston Museum of Science, the following students were honored. Salman Akhtar received the Frederick C. Hennie III Award; Derek R. Curd received the Northern Telecom/Bell-Northern Research Inc. Award; Christopher A. Cooke, Todd E. Knibbe, and Karl Sun, the George C. Newton Undergraduate Laboratory Prize; and a George M. Sprowls Scholarship Fund Award went to Katherine A. Yelick for her Ph.D. thesis. John R. Buck was promoted to Instructor-G.

Straight 'T' Athletic Awards are the highest awards given for athletic performance and were given out at the Institute's May Awards Convocation; one was earned by VI-A swimmer James H. Bandy.

The Office of Minority Education awards for achievement in academic and extracurricular activities went to 76 students of which seven are enrolled in the VI-A Internship Program.

Excellence in scholarship continues amongst the students in the Program. Of 133 seniors from the School of Engineering elected to Tau Beta Pi, the National Engineering Honorary, 35 were VI-A's and Eta Kappa Nu, the Course VI Honorary, elected 121 members of whom 53 were VI-A's. Six students were also elected to Xi Chapter of Phi Beta Kappa.

MICROSYSTEMS TECHNOLOGY LABORATORIES (Professor L. Rafael Reif)
The Microsystems Technology Laboratories (MTL) carry out research in the fabrication and study of small monolithic structures and their use for the implementation of interesting integrated systems from X-ray lenses to VLSI circuits. The expanding and dynamic research program covers solid state devices, integrated circuits, materials for electronic applications, novel process technologies, sensors and actuators, and computer-aided fabrication. The MTL houses three clean room facilities (the Integrated Circuits Laboratory - ICL, the Technology Research Laboratory - TRL , and the Submicron Structures Laboratory - SSL), an associated non-clean laboratory space (the Research Group Laboratories - RGL), and the Computational and Communication Network facility. The centerpiece facility of the MTL is the Integrated Circuits Laboratory, a state-of-the-art class-10 clean laboratory with full capabilities for modern IC fabrication. The laboratory is operated by full time technical staff and graduate students.

The research dollar volume for FY92 was approximately $10.5 million. The personnel involved include over 25 faculty, 4 senior research staff, 170 graduate students, 11 post-doctoral fellows, 17 visiting scientists, 45 undergraduate students, 22 technical support staff, and 11 administrative and support staff. These faculty and personnel represent affiliations including the Departments of Electrical Engineering and Computer Science, Materials Science and Engineering, Chemical Engineering, Mechanical Engineering, Brain and Cognitive Sciences, Civil Engineering and Physics; the Center for Materials Science and Engineering, the Research Laboratory of Electronics, the Laboratory for Electromagnetic and Electronic Systems, the Laboratory for Information and Decision Systems, the Laboratory for Computer Science, the Center for Space Research, and the Turbulence Research Laboratory. During the 1991-92 academic year, 42 Ph.D. and 23 S.M. degrees were awarded in conjunction with this research.

Research in MTL may be grouped into eleven categories:

(1) **Integrated Circuits** include analog and digital integrated circuit (IC) design as well as advanced process development for "mixed analog/digital signal" IC applications.

(2) **Integrated Sensors** include technologies for micromachining, design of microsensors and microactuators, and the application of these devices to physical and chemical measurements.

(3) **Power Devices and Circuits** include research in very high frequency power converters, power device performance, and novel fabrication procedures for energy storage devices.

(4) **Electronic Devices** include research on novel devices operating in the semi-classical regime.

(5) **Quantum Effect Electronics** include novel device structures designed specifically to study and explore quantum mechanical effects arising from carrier interactions with features of sub-100 nm dimensions.

(6) **Submicron and Nanometer Structures** include some "nanofabrication" projects that are not directly related to electronic devices. The Submicron Structures Laboratory develops techniques

for the fabrication of surface structures with feature sizes in the range of nanometers to micrometers, and uses these structures in a variety of research projects.

(7) **Process and Device Modeling and Simulation** covers the use of numerical techniques that solve complex problems of carrier transport and device operations as well as physical problems that arise during materials and device processing.

(8) **Fabrication Technology** covers a broad area of processing and device fabrication with two main themes: novel processes for integrated circuit and device fabrication in silicon and compound semiconductors, and fundamentals underlying materials processing effects.

(9) **Computer-Aided Fabrication** includes computer-based modeling and simulation of fabrication processes and execution in a realistic fabrication environment; work flow scheduling; process equipment modeling and process control; and microstructure/ mechanical property simulation.

(10) **Materials,** with the common theme of growth and characterization of thin films for electronic applications, include research of novel silicon and silicon-germanium epitaxy, the formation of heterostructures in compound semiconductors, polyimides in microelectronics, and the study and control of the crystalline structure of very thin films.

(11) **Packaging** includes advanced chip assembly and study of passivating properties of different materials in thin film form.

The MTL facilities are supported in part by members of the MIT Microsystems Industrial Group, whose current members include: Analog Devices, Inc.; AT&T; Digital Equipment Corporation; Draper Laboratories; General Motors Corporation; Hewlett-Packard Company; IBM; Intel Corporation; Motorola, Inc.; Polaroid Corporation; Raytheon Company and Texas Instruments.

Coordination activities carried out by MTL include a weekly VLSI Seminar Series, MTL Memo Series, and an annual Microelectronics Research Review. The MTL publishes an annual report entitled *Research in Microsystems Technology at MIT.*

FACULTY

The department welcomed Gregory W. Wornell, Assistant Professor of Electrical Engineering, to the faculty this year. He received his Ph.D. at MIT.

Associate Professors William J. Dally and William E. Weihl were awarded tenure this year.

Associate Professors Robert C. Berwick, Shafrira Goldwasser, Charles E. Leiserson, Terry P. Orlando, Charles G. Sodini, George C. Verghese, and Markus Zahn were promoted to Professor. Assistant Professors Anant Agarwal, Srinivas Devadas, Martha L. Gray, Leslie A. Kolodziejski, and Martin A. Schmidt were promoted to Associate Professor.

Once again this year, many members of the faculty were recognized with honors and awards:

Professor Harold Abelson was named a MacVicar Faculty Fellow as part of a new program honoring the late dean for undergraduate education. Abelson was recognized as a patient mentor, skillful teacher, insightful scientist, and a pioneer in computer science education. He also received, with Professor Gerald J. Sussman, the Amar Bose Teaching Award. That award, made annually for outstanding teaching in the School of Engineering, recognizes Abelson's and Sussman's development and teaching of 6.001.

The National Science Foundation Presidential Young Investigator Awards went to Associate Professors Anant Agarwal, Munther A. Dahleh, Jesús A. del Alamo, Martha L. Gray and Martin A. Schmidt.

Associate Professor Anant Agarwal was named Jamieson Career Development Associate Professor of Computer Science and Engineering.

Professor Arvind was named Charles W. and Jennifer C. Johnson Professor of Computer Science and Engineering.

Professor Amar G. Bose was elected a Fellow of the American Academy of Arts and Sciences.

Professor H. Kent Bowen was elected a Fellow of the American Academy of Arts and Sciences.

Assistant Professor James E. Chung was named Analog Devices Career Development Assistant Professor of Electrical Engineering.

Professor Michael L. Dertouzos was awarded an honorary doctorate by the Polytechnic University of Athens.

Associate Professor Martha L. Gray was selected as the first recipient of the Ruth and Joel Spira Teaching Award. The award was established to recognize outstanding performance in both research and teaching by a junior faculty member.

Citing his "outstanding efforts to create an atmosphere of change and an environment supportive to women engineers," the Society of Women Engineers gave its Chipp Memorial Award to Chairman, President Emeritus and Professor Paul E. Gray. In addition, Professor Gray was decorated by the Emperor of Japan as Grand Cordon of the Order of the Sacred Treasure in recognition of "meritorious services rendered through the years for the promotion of friendly relations and mutual understanding between the two countries."

Institute Professor Hermann A. Haus was elected a Fellow of the American Physical Society.

Assistant Professor Qing Hu was named KDD Career Development Assistant Professor of Electrical Engineering.

The City of Philadelphia honored Professor Erich P. Ippen with its John Scott Award, in recognition of his pioneering development of ultrashort laser pulses which "represent lasting contributions to science and our society."

Associate Professor Leslie A. Kolodziejski was appointed Karl R. Van Tassel Career Development Associate Professor of Electrical Engineering.

Professor Barbara H. Liskov was elected a Fellow of the American Academy of Arts and Sciences.

Assistant Professor Gregory M. Papadopoulos was named Class of 1922 Career Development Assistant Professor of Electrical Engineering and Computer Science.

Professor Jerome H. Saltzer was elected a Fellow of the American Association for the Advancement of Science.

Associate Professor Martin A. Schmidt was named Carl Richard Soderberg Associate Professor in Power Engineering.

Professor Emeritus William F. Schreiber was elected a Fellow of the Society of Motion Picture and Television Engineers. In addition, the International Society for Optical Engineering honored Professor Schreiber with its Gold Medal in recognition of his lifelong pioneering work in the field of image processing and electronic imaging systems.

Assistant Professor Lynn A. Stein was named Class of 1957 Career Development Assistant Professor of Computer Science and Engineering. She also received the General Electric Foundation's Junior Faculty Career Award.

Professor Kenneth N. Stevens received the Voice Foundation's Quintana Voice Research Award.

Professor Peter Szolovits was elected a Fellow of the American Association of Artificial Intelligence.

Professor Thomas F. Weiss was named the first Thomas and Gerd Perkins Professor of Electrical and Bioengineering.

Professor Emeritus Joseph Weizenbaum received an honorary doctorate from Daniel Webster College.

Professor Emeritus and President Emeritus Jerome B. Wiesner was honored with the National Science Board's Vannevar Bush Award in recognition of his outstanding contributions in science and technology that are significant to the national welfare. He has been called "the conscience of the scientific community" for contributing to public understanding of the risks of the nuclear age and for his efforts to reduce those risks.

Several faculty were away this year:

Professor Louis D. Braida spent the spring term pursuing new research projects concerned with the measurement of facial actions that occur as a consequence of speaking.

Professor Tomás Lozano-Pérez was away during the fall term exploring a new research area of computational biochemistry.

Professor Silvio Micali spent the fall term exploring the design of communication protocols that may be helpful in understanding certain aspects of immunology.

Professor Alan V. Oppenheim spent the academic year at Woods Hole, Tel Aviv University and the University of Hawaii working on several textbooks and exploring new research in signal processing.

Professor Ronald L. Rivest was away during the fall term working on new research in machine learning.

Professor Gerald J. Sussman spent the academic year at several California universities working on ideas relating quantum mechanics to the semantics of parallel programming languages.

Professor Cardinal Warde spent the spring term working with the National Association for Equal Opportunity in Higher Education on the development of a government-sponsored program that would establish a scientific research center of excellence at a historically black university.

Professor Thomas F. Weiss spent the fall term working on new research and on a text for cellular physiology and biophysics.

Three visiting faculty members joined the department this year, sharing research and teaching:

Visiting Professor Elwyn Berlekamp came from the University of California, Berkeley, to pursue research in the fields of encoding and game theory with Professor Peter Elias' group and to teach two subjects.

Visiting Professor Thomas Kailath, from Stanford University, spent the fall term with Professor Sanjoy K. Mitter teaching a graduate subject and working on research in the fields of information theory, communications, computation control, and operator theory.

Visiting Associate Professor Jeannette M. Wing, from Carnegie Mellon University, spent the spring term teaching and working with Professor John V. Guttag on research in the areas of programming languages, distributed and concurrent systems, formal specifications, object management and visual languages.

Professors Peter Elias and David C. White retired from the faculty this year. Professor Elias will continue in the department as a Senior Lecturer.

We note with sadness the death on October 24 of Professor Emeritus Richard H. Frazier at age 91. Professor Frazier received the S.B. and S.M. from MIT, was a founding member of the MIT chapter of Tau Beta Pi in 1922 and was on our faculty until his retirement in 1965. He specialized in the fields of instrumentation and electromechanics and helped develop many high-performance actuators. Toward the end of his career he worked on electromechanical control elements for spacecraft guidance. He was affiliated with the Instrumentation Laboratory (now Draper Laboratory) and advised students from our department doing theses there. His entire teaching career was at MIT, except the year 1935-36 when he served as department head at the University of Kansas. During World War II he taught in military programs and also carried a heavy administrative load; he ran the graduate office after the war and served as chairman of the Institute Committee on Libraries. He regularly taught subjects in instrumentation and also subjects that are now known as 6.002 and 6.003.

PAUL PENFIELD, JR.

Department of Materials Science and Engineering

SUMMARY

The academic year 1991-1992 was an excellent one for our department. Our undergraduate body increased somewhat and now averages 46 per class. Our graduate body is stable and even increasing somewhat after an intentional downsizing over the last several years. We expect a graduate school of approximately 190 in the fall of 1992. We will admit in September the largest incoming graduate class since 1985: it will comprise approximately 71% domestic students, 26% women and 6% under-represented minorities. During the academic year 1991-1992 we awarded 44 bachelors degrees, 31 masters degrees and 28 doctorates.

We added two new faculty members to our ranks this year. Professor Gerbrand Ceder joined us as Alcoa Assistant Professor of Materials Science and Engineering. His area of specialization is mathematical modelling in materials science. Professor David C. Dunand joined us as AMAX Assistant Professor of Materials Engineering. His area of specialization is high temperature materials processing and properties.

During our faculty search process in 1991-1992, we reviewed some 500 applications and interviewed 13 candidates on campus. From this group we hired Dr. Anne M. Mayes, who will join our faculty at the end of calendar year 1992 to teach and conduct research in the area of polymers. Dr. Mayes did her graduate work at Northwestern, and is currently a postdoctoral associate at IBM Almaden Research Center.

With respect to our undergraduate program, our textbook initiative is proceeding on schedule. In addition, we are undertaking a major project to introduce a new undergraduate laboratory in materials processing, in which students will have hands-on experience in processing of the several materials classes.

An important celebration during 1991-1992 was the initiation of the Sumitomo Electric Industries Professorship and creation of the Harry C. Gatos Distinguished Lecture and Prize in Materials Science and Engineering, both funded by Sumitomo Electric Industries, Ltd. The first recipient of the Professorship is Professor Harry L. Tuller of this department, internationally recognized for his work on the development and characterization of electrically and optically active ceramics and glasses, and their application to energy conversion, electronic devices and sensor technology. Harry C. Gatos, a member of our faculty for nearly three decades until his retirement in 1990, played a key role in the development of the science of electronic materials, especially gallium arsenide. He led this department's activities into the field of electronic materials by forming, in 1962, the first electronic materials group within a materials department. For some years it was the only academic group devoted to the study and establishment of relationships among crystal growth parameters, structural and chemical composition, and electrical properties.

The Gatos Lecture and a $5,000 prize will be awarded, generally every two years, to an individual who has contributed significantly to the advancement of the field of materials science and engineering.

We note with regret the death of Benjamin L. Averbach on April 1, 1992. Ben joined the department in 1945 as a Research Assistant, and over his career published more than 200 papers on a variety of materials subjects, including transformations in steels, determination of atomic arrangements in amorphous materials, developments of analytical techniques in x-ray, electron and neutron diffraction, fracture phenomena in ships, pipelines and aircraft. He became an emeritus professor in 1990, and continued to serve the department as Chairman of our Safety and Hygiene Committee.

We note with some satisfaction and hope for the future that materials science and engineering has been singled out in the President's fiscal year 1993 budget for a major infusion of new support in the form of a Presidential Initiative, the "Advanced Materials and Processes Program" (AMPP). In announcing this initiative last January, Dr. D. Allan Bromley, the Assistant to the President for Science and Technology, said, "This Presidential Initiative recognizes that materials are at the heart of essentially all of today's advanced technologies, and materials research and development thus has very broad applications. This program will greatly increase the effectiveness of federal R&D programs in materials through coordination among the agencies and with the private sector.... We are entering the age of tailored materials, and an unprecedented number and range of opportunities await materials researchers."

Five faculty members were promoted during the academic year 1991-1992. Professors Samuel M. Allen, Carl V. Thompson and Donald R. Sadoway were promoted to Full Professor, and Professors Michael J. Cima and Andreas Mortensen were promoted to Associate Professor with tenure. We welcome these last two faculty members to our permanent staff.

THE UNDERGRADUATE PROGRAM

Our undergraduate textbook initiative continues to make satisfactory progress. We now have some five textbooks in various stages of completion, one or more of which is nearing publication. Continued fine tuning of undergraduate subjects and rotation of instructors have resulted in an undergraduate program that brings high marks from our students and faculty.

A major effort of the department during this current year has been the development of a new laboratory in materials processing. Last year the faculty concluded we might now be ready to teach a single materials processing-property laboratory that would stretch across all materials classes. A special task force led by Professor Michael F. Rubner studied the question in detail during the fall of 1991, and recommended institution of such a laboratory. The plan was approved by the faculty, and Professor Rubner's committee then spent the spring and summer of 1992 in developing the subject content and overseeing necessary laboratory space changes and equipment acquisition. The laboratory will be initiated in the fall of 1992. Its hallmark will be student hands-on experience in processing of real materials in the several materials classes.

Our undergraduate enrollment remains at historically high levels and we expect a modest increase this coming fall. Essential to maintaining our undergraduate body are extensive recruiting efforts, including a 3-day Open House, our annual John Wulff Lecture, and direct mailings to the freshman class. Our III-B "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 35 companies and government laboratories while providing summer experiences for our undergraduates which are relevant to their educational development. Perhaps needless to say, placement of students during the summer of 1992 was unusually difficult, but all eventually found suitable positions.

Our undergraduate body currently comprises 47% women and 13% underrepresented minorities, and 5% foreign students. We awarded 44 bachelors degrees in 1992.

GRADUATE ADMISSIONS AND THE GRADUATE PROGRAM

We anticipate for the fall of 1992 a graduate class of about 190. Barring unexpected funding difficulties, we anticipate continued slow growth in this number over the coming few years.

We are continuing to be able to maintain and even increase a little our percentage of domestic students in graduate school. The program we adopted three years ago of offering one-term fellowships to most domestic applicants, has paid off handsomely. Although our admissions process is not quite complete for this year, we now estimate that we will register an incoming class of 51 for the coming fall, 71% of which will be domestic. This will be the highest percentage of domestic students we will have admitted in over ten years, and the largest class that we will have admitted since 1985.

The strengthening of our graduate body indicated by the above numbers is due in part to the increasing popularity of our field. It is also a result of the strenuous and effective efforts of our Graduate Admissions Committee under the Chairmanship of Professor Kenneth C. Russell. Finally, it is a result also of our decision to make graduate fellowships a top fund-raising priority of the department. These fellowships are particularly attractive to incoming students since they provide students a breathing period in which they can become acquainted with MIT, and can choose with some forethought their thesis topic and thesis supervisor. Of our 36 domestic students expected to enter in the fall of 1992, 27 will be entering on fellowships. Of these, 14 are fellowships granted directly by our department; the remainder are from a variety of sources including NSF, DOE, DOD, and private foundations.

Approximately 32% of our graduate students are women and 3% are underrepresented minorities. The distribution of our students among our six graduate degree programs and their affiliates is little changed from last year. As of February 1992 it was:

Degree Program	Percent of Total Graduate Students
Ceramics	15%
Electronic Materials	20%
Materials Engineering	23%
Materials Science	9%
Metallurgy	14%
Polymers	19%

One of our students in Materials Engineering was enrolled in the Technology and Policy Program of MIT, and four were enrolled in our the Leaders for Manufacturing Program. Nearly half of our Polymer students were enrolled in our Program for Polymer Science and Technology.

After a year of discussion and planning we expect during the coming year to introduce our new "Industrial Fellows Program," in which we seek industrial interaction in a form which includes sponsorship by companies of graduate fellowships within the department. Descriptive brochures will be available in the fall.

PROFESSORSHIPS AND GRANTS TO ENDOWMENT

During the last year, three faculty members of this department were appointed to newly received endowed chairs. Professor John B. Vander Sande was appointed Cecil and Ida Green Distinguished Professor; Professor Harry L. Tuller was appointed Sumitomo Electric Industries Professor of Engineering; and Professor David C. Dunand was appointed AMAX Career Development Professor of Materials Engineering.

Faculty of this department now occupy 12 endowed chairs. In addition to the three noted above, the chairholders are: H. Kent Bowen, Ford Professor of Engineering; Yet-Ming Chiang, Kyocera Associate Professor of Ceramics; Joel P. Clark, POSCO Professor of Materials Science and Engineering; Thomas W. Eagar, Richard P. Simmons Professor of Metallurgy; Merton C. Flemings, Toyota Professor of Materials Processing; Lionel C. Kimerling, Thomas Lord Professor of Materials Science and Engineering; Uday B. Pal, John Chipman Assistant Professor, Edwin L. Thomas, Morris Cohen Professor of Materials Science and Engineering; August F. Witt, TDK Professor of Materials Science and Engineering.

Term chairs, especially those held by junior faculty members, are of immense value to the holders in building their careers. Chairholders and chairs for the academic year 1991-1992 were: Stuart B. Brown, Richard P. Simmons Associate Professor of Materials Manufacturing; Gerbrand Ceder, ALCOA Assistant Professor of Mechanical Metallurgy; Michael J. Cima, Norton Associate Professor of Ceramics Processing; Thomas W. Eagar, Leaders for Manufacturing Professor of Materials Engineering; Kirk D. Kolenbrander, Carl Richard Soderberg Assistant Professor of Electronic Materials; Manuel P. Oliveria, Elisha Gray II Assistant Professor of Materials Science and Engineering, Michael F. Rubner, Class of '57 Associate Professor of Polymer Physics.

Nearly all undesignated gifts to the department are currently being used to fund endowed fellowships (including the Nicholas J. Grant Fellowship, the John F. Elliott Fellowship, the Ronald A. Kurtz Fellowship, the Gilbert Y. Chin Fellowship, the David V. Ragone Fellowship, the Stuart Z. Uram Fellowship, and the Class of '39 Fellowship). These now provide sufficient annual income for one term fellowships for approximately 5 students.

FACULTY

During this academic year, Professor Robert W. Balluffi was the Thomas Reed Memorial Lecturer at the University of Illinois, the Herbert Johnson Memorial Lecturer at Cornell University, and the Van Horn Distinguished Lecturer at Case Western Reserve University. Professor H. Kent Bowen was elected Fellow of the American Academy of Arts and Sciences. Dr. Paul D. Bristowe was appointed Fellow of the Institute of Physics, London. Professor Peggy Cebe received a U.S. Army Summer Faculty Research Award and was awarded an AT&T New Research Fund Award. Professor Gerbrand Ceder received the André-Deruyttere Prize of the Materials Science Department at the K. U. Leuven, was awarded an AT&T New Research Fund Award, and was appointed Alcoa Assistant Professor of Materials Science and Engineering. Professor David C. Dunand received the 1991 Aesar/Alfa Research Grant for Excellence in Technical Research and was appointed AMAX Assistant Professor of Materials Engineering.

Professor Thomas W. Eagar received the Charles H. Jennings Memorial Medal of the American Welding Society and was Comfort A. Adams Lecturer of the AWS. Professor Merton C. Flemings was a co-recipient of the Sawamura Prize for best paper in the Japan Iron and Steel Institute Journal, 1991. Professor Lionel C. Kimerling was John E. Dorn Memorial Lecturer at Northwestern University, and is Vice President Elect of TMS for the 1992-93. Professor Kirk D. Kolenbrander was appointed Carl Richard Soderberg Assistant Professor of Electronic Materials. Professor Ronald M. Latanision was appointed Visiting Professor of the University of Naples, Italy, and was made honorary MIT Alumnus. Adjunct Professor Robert A. Laudise was elected to the National Academy of Sciences. Professor Heather N. Lechtman was Walter W. S. Cook Lecturer, Institute of Fine Arts, New York University. Professor Andreas Mortensen received the 1991 Marcus A. Grossmann Young Author Award for best paper in *Metallurgical Transactions* by authors under 40 years of age.

Professor Julian Szekely received the TMS Educator Award (1991), the Alexander von Humboldt-Stiftung Prize (1992), and was appointed Honorary Member of the Hungarian Academy of Engineering (1992). Professor Harry L. Tuller was appointed Sumitomo Electric Industries Professor of Engineering. Professor John B. Vander Sande was appointed Cecil and Ida Green Distinguished Professor. Professor August F. Witt received the Space Processing Award of the American Institute of Aeronautics and Astronautics, 1992. Professor Ioannis V. Yannas received the Clemson Award for Applied Biomaterials Research of the Society for Biomaterials.

A Festschrift, entitled Martensite and edited by G. B. Olsen and W. S. Owen, was published by ASM International as a tribute to Morris Cohen on the occasion of his 80th Birthday (which occurred in 1991). The Festschrift consists of papers on martensite transformations by leaders in the field from around the world to review and update this technologically profound subject, which has been the basis of much of Professor Cohen's research over the years. As Professor Cyril Smith wrote in his contributed article: "The very essence of the modern approach to materials that Morris Cohen has done so much to promote lies in the appreciation of the diversity of their properties and uses combined with theoretical understanding, which enables better control of production and also suggests new structural combinations."

UNDERGRADUATE STUDENTS

The Student Undergraduate Materials Society (SUMS) continued to be a 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: Scott Jacobsmeyer (President), Karina Rigby, (Vice President), Andrea Wang (Secretary), and Lawrence Foley (Treasurer). New officers elected in spring 1992, are: Julie Stein (President), David Gomez (Vice President), Shilpa Gadkari (Secretary), and Amy Rochelle (Treasurer).

Two students, Darren T. Castro and Janelle Gunther and were invited to join Phi Beta Kappa. The fall initiates for The Tau Beta Pi Engineering Honor Society were: Douglas Blom, Lawrence Foley, Sherry Ipri, Nicole Lozo, Roy Rasera (Class of 1993), and Albert Cheng, Kaichu Hsieh, Dinesh Lathi, and Adam Clayton Powell IV (Class of 1992). Xiao-Guang Sun (Class of 1993) was initiated in May.

Nine students were accepted as associate members in the Society of Sigma Xi, The Scientific Research Society of North America: Darren Castro, Albert Cheng, Matthew Galla, Janelle Gunther, Scott Jacobsmeyer, Dinesh Lathi, Adam Powell, Barbara Sweet, and WeeJyn Tan

Darren T. Castro received the Best Senior Thesis Award. Saskia Duyvesteyn received the Best Cooperative Project Report. Scott Jacobsmeyer received one of four $2,000 scholarships presented by The Minerals, Metals & Materials Society (TMS).

GRADUATE STUDENTS

Newly elected members of the Graduate Materials Council (GMC) are: Robert Calhoun (Chairman), Ann Redsten (Vice Chairman), Beth Stadler (Treasurer), Donna Chuang and Frank Ren (DCGS Representatives), Frank Ross, Chris Coronado and Cindy Bedell (GSC Reps), Frank Ross (Social Chair), and Ali Farah and Kathy Chen (MESS Seminars). Officers of the society during academic year 1991-1992 were Chris Coronado (Chairman), Donna Chuang (Vice Chairman), Isako Hoshino (Treasurer), Bruce Pint and Richard Mlcak (DCGS Representatives), Robert Calhoun and Frank Ross (Social Chairs), Tami Fletcher (MPC Representative), and Ali Farah (MESS Seminars). GMC continued its seminars and monthly socials. It continued to undertake the supervision of the arduous but important task of course evaluations.

Officers of the MIT Student Chapter of the Materials Research Society during the academic year 1991-1992 were Bethanie Hills (Chairman), Mariflor Salas-Morales (Vice Chairman), and Julie Tsai (Treasurer). The group organized a series of lectures on Materials Research in Industry, with speakers discussing opportunities in materials research at their respective companies.

This student chapter was replaced at the end of academic year 1991-1992 by the newly formed Association of Materials Students Societies (aMaSS), a coalition of student chapters of six materials professional societies: Materials Research Society (MRS), ASM International/The Materials Society (ASM/TMS), Society for the Advancement of Materials Processing and Engineering (SAMPE), the Electrochemical Society (ECS), the Society of Plastics Engineers (SPE), and the American Ceramics Society (ACS). Officers of aMaSS for 1992-1993 are: Jimmy Chen (Chairman), Beth Stadler (Vice Chairman), Arun Seraphin (Treasurer), and Heather Inglefield (Secretary). The Chairmen of the six student chapters are: Monica Kaforey (MRS), Ann Redsten (ASM/TMS), Kathy Chen (SAMPE), Rick Mlcak (ECS), Sharon Liu (SPE), Beth Stadler (ACS). The association was formed with the purpose of increasing the profile of MIT in the professional society of materials research. Membership is offered to undergraduate and graduate students, from all departments of MIT, who are interested in materials.

Three graduate students were accepted as associate members in the Society of Sigma Xi, The Scientific Research Society of North America: Roland Carel, Katherine Chen, and Tracy Harrison. Twelve students were accepted as full members: Georges Abou-Chedid, Francois Billaut, Zuezhong Cao, Anacleto Figueredo, Sharone Furçone, Catherine Heremans, Jeri Ann Ikeda, William MacDonald, Paul McIntyre, Leonard Rubin, Deborah Vezie, and Lock See Yu-Jahnes.

Fellowship Awards for one or more semester were held during academic year 1991-1992 by 51 students.

Samuel P. Gido received the MRS Student Award at the fall, 1991 meeting. Paula Hammond received the MIT Karl Taylor Compton Award. Chang-kyung Kim was co-recipient along with Professor Linn W. Hobbs of the Best Poster Award at the 1991 Gordon Conference on Corrosion. John Moalli and Livia Racz were co-recipients of The John Wulff Award for Excellence in Teaching.

FACULTY AND STAFF RESEARCH ACTIVITIES

Some selected research achievements include the following: Professor Ceder has solved the long-standing problem of finding all FCC-alloy superstructures that can be stabilized by atomic interactions up to the fourth nearest neighbor distance, and computed the first ever *ab-initio* phase diagram with this interaction range. Professor Kimerling's research on strain relaxation in SiGe/Si heterostructures provided the first measure of strain distribution, showing that dislocation propagation into the substrate is caused by an over-relaxation of tensile strain in the film. Professor Kolenbrander has fabricated his first quantum dot/host composite materials using his novel gas-phase synthesis and processing techniques. He is presently characterizing these materials to evaluate their performance as a possible new class of photonic materials. Professor Rubner's group has also fabricated new thin film heterostructures comprised of molecular layers of electrically conductive polyions. Professor Wuensch continued his search for new alkali-ion fast ion conductors and in the process synthesized a rich collection of phases, at least nine of them new.

MERTON C. FLEMINGS

Department of Mechanical Engineering

INTRODUCTION AND GENERAL REMARKS

The mechanical engineering profession encompasses a very broad area. The profession is concerned with energy, motion and materials, and the design, production and management of systems to meet the needs of society. Mechanical engineering will play a crucial role in addressing the challenges of the next decade relating to the supply and efficient utilization of energy, enhancement of the environment, manufacture of goods and services, safe and efficient transportation systems, health care and human rehabilitation, and imaginative use of information and information technology.

Mechanical engineering practice is changing rapidly due to advances in science and technology, and changing societal needs. The increasing capability of computation, information processing, sensing and control technology, the growing ability to synthesize and process new materials, fundamental changes in manufacturing technology, an improved understanding of the life sciences and human factors, the ability to provide new solutions at the interfaces of disciplines, societal demand for greater safety and reliability, and, most of all, advances in fundamental disciplines of engineering, all contribute to this change. These rapid changes provide both significant challenges and opportunities to the profession and for the education of future engineers.

The department is consistently rated as the *best* mechanical engineering department in the United States. It is also one of the largest departments in MIT, with more than ten percent of the Institute's undergraduates and ten percent of the graduate student population. The department has earned its reputation through its ability to attract the best students and faculty, to respond to changing societal and national needs, and to lead the profession with its innovative ideas and programs in education and research. Over the years, it has created and established strong programs in energy, transportation, biomedical engineering, acoustics, manufacturing, and environmental engineering. These achievements have been possible because the department has maintained its high standard of excellence in the basic disciplines of mechanical engineering, i.e., solid mechanics, fluid mechanics, thermal sciences, materials, control, systems, and design. At the same time, the department has expanded the traditional definitions of mechanical engineering through its innovative approach to new problems facing the field of mechanical engineering. This tradition of pioneering new scientific and technological frontiers, while remaining firmly grounded in fundamental engineering science, is alive and well in the department as evidenced by numerous emerging activities such as those in information technology and other areas. The goal of the department is to maintain this powerful blend of strong traditional teaching and research and innovative approaches to areas of new intellectual challenges and opportunities to make fundamental contributions to humankind through the generation of outstanding human resources, knowledge and technology.

The research programs of the department remain strong. The research volume of the department is approximately $8.5 million, or $17 million with interdepartmental organizations factored in. The department receives approximately 46 percent of its funding from both industry and private foundations. In addition to those interdepartmental research programs mentioned below, faculty members have initiated new research projects in all areas of mechanical engineering. However, the increase in research funding has not kept up with the increase in research costs in recent years. Therefore, efforts have been initiated to generate funding for large group research in view of the changing posture for research support at the national and international level. This also encourages and enhances opportunities for collaborative research in engineering systems. The department has funded two projects as a first step in developing strong research activities in new high risk/high return areas, which could have difficulty in receiving external funding during the formative stage because of their unusual nature. The projects are "Droplet-Based Manufacturing" (DBM) and "Design and Control of Precision Systems: Advanced Data Storage Systems." The first project will advance the understanding of fluid-thermal phenomena in DBM processes where capillary, viscous, and inertial forces play important roles due to the small size of the droplets. The second will explore new approaches to increasing data storage capacity by several gigabytes in less than one third of an inch diameter disk using the technologies of the scanning tunneling microscope and the magnetic force microscope, thus enabling access to atomic size information. In order to support such research projects and other initiatives to expand the traditional bounds of mechanical engineering, external fund raising activities are of critical importance to the department.

The faculty of the department are committed to excellence in classroom teaching and mentorship in individual interactions. Teaching evaluations by students are taken seriously by the department and their suggestions for improvements are adopted on a timely basis. The department has pioneered important paradigms in undergraduate design, fluid mechanics, and manufacturing subjects, among others. Outside demand for students graduating with SB and SM degrees has been strong. The demand for doctoral graduates interested in engineering education is still good, although a significant reduction in the hiring of new faculty members has taken place recently due to the financial constraints imposed on a large number of leading universities.

The department is committed to interdepartmental education and research programs, many of which are led by faculty members of the department. The New Products Program, founded and directed by Professor Woodie Flowers, is growing and receiving strong support from both industry and students. The Leaders for Manufacturing Program (LFM), co-directed by Professor John Heywood, has had a positive impact on MIT. In the past academic year, nine mechanical engineering professors have supervised nearly half of the LFM students. The Laboratory for Manufacturing and Productivity, headed by Professor David Hardt, has a large number of department faculty members providing effective leadership in education and research in manufacturing. The department also strongly supports the interdepartmental effort by Professors Roger Kamm and other colleagues to organize an interdepartmental biomedical engineering group at MIT. The involvement of department faculty in environmental research, headed by Professor Ronald Probstein, is also increasing. These and other interdepartmental activities are important elements in the unique culture and excellence of the department's educational and research programs.

Notwithstanding the strengths of its long-standing educational programs, the department has periodically reviewed its curriculum for undergraduates and graduate students. The current undergraduate curriculum was established in 1972 under the leadership of Professors Herbert Richardson and Ascher Shapiro, with a few modifications in subsequent years. A major review of the undergraduate curriculum was initiated in 1989 by a group of faculty under the leadership of Professors Kamm and David Wormley. Over the past year, an ad hoc Curriculum Development Committee has continued to examine the curriculum. An ad hoc Graduate Study Committee will be undertaking an evaluation of graduate education in AY 1992-93.

In addition to examining formal instructional programs, the department has undertaken initiatives to enhance the learning and cultural environment for all of its students. The goals are to expose the student to contemporary technological and societal issues and to provide them with a broader perspective on their role in society. This is done through a new seminar series called *Distinguished Alumni/ae Lecture Series*, sophomore picnics, semi-annual letters to undergraduate and graduate students from the department head, and departmental support of student activities.

The department is fortunate in that it can provide a better learning environment for women students than a few years ago. It now has four outstanding women professors on its faculty who have been instrumental in initiating activities to provide information to women students, to attract more women students into doctoral programs, and to enhance employment opportunities for women students. Their efforts will continue. The department has not been as successful in attracting more underrepresented minority faculty members. The solution to this problem is an urgent task for this department.

A major effort is under way for the development and improvement of facilities and equipment of teaching and research laboratories in the department. The goal is to endow most of these laboratories to ensure their continued maintenance and modernization in future years. To this end, the Heat Transfer Laboratory is being completely renovated and will be dedicated as the Warren M. Rohsenow Heat Transfer Laboratory in September 1992. The department also received funding from an industrial firm for the Mechanical Behavior of Materials Laboratory which will be dedicated during the spring of AY 1992-93.

The department needs additional funds for chaired professorships, graduate fellowships, and research. The department has been working with the development offices of MIT to raise funds to honor a large number of senior faculty members of the department, to attract more outstanding graduate students, and to lead in research. The creation by the Daewoo Corporation of Korea of the Sun Jae Professorship in the department during AY 1991-92 was an important step in achieving this goal.

The department is in the midst of re-examining its structure. The goal is to promote greater synergistic interactions among the faculty, to provide mechanisms for collegiality among a wider circle of colleagues, and to recognize and reward contributions made by the faculty both in disciplinary and systems teaching and research. Since early actions taken by the department head were controversial, an ad hoc Committee on Departmental Goals and Structure has been established to develop a consensus-based structure for the department.

In the following sections, the details of departmental activities in teaching, research, and service are presented.

PROGRAMS OF INSTRUCTION

Objectives

The overall educational objective of the department has not changed in 40 years: to educate people to become leaders in industry, education, research, and public service. To this end, the department provides a strong disciplinary foundation, opportunities to learn interdisciplinary subjects, experience in solving contemporary scientific and technological problems, and intellectual exposure to socioeconomic and political issues.

The cornerstone of the department's educational plan is the strong interaction between distinguished faculty and highly motivated, intelligent students. The goal of undergraduate education is to provide a broad educational background in mechanical engineering to prepare students for changing technological opportunities and societal needs. The graduate program is designed to educate professionals and scholars in the field of mechanical engineering.

Undergraduate Programs

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 in Mechanical Engineering without specification (Course II-A) also 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.

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 such areas as biomedical engineering, management, and energy policy with mechanical engineering. About 30 students are enrolled in Course II-A. Course II-B averages about 25 students entering the program each year, representing about 20 percent of the eligible sophomores. Currently about half of the mechanical engineering sophomores entering the program continue to the graduate degree.

The department enrollment continued at levels comparable to the past few years, with about 445 undergraduates at the end of the spring term. As of the fall term, the enrollment included 107 women and 81 underrepresented minorities from a total of 167 minority students.

In 1991-92, the department awarded 111 Course II degrees, 14 Course II-A degrees, and 14 Course II-B degrees.

Undergraduate Curriculum Development

An ad hoc Undergraduate Curriculum Development Committee (Professors Bora Mikic [Chair], Flowers, Heywood, Kamm, Jung-Hoon Chun, Markus Flik, David Gossard, Peter Griffith, David Parks, Carl Peterson, Emanuel Sachs, and Jean-Jacques Slotine) has been established to re-examine the undergraduate curriculum and make recommendations to the department regarding an improved undergraduate curriculum. Its work has generated serious discussion in the department, although its final recommendations have not yet been made. Also, as part of the MIT-wide activity for *Teaching in a Research University*, Professors Flowers and Robert Mann organized departmental symposia on this subject. A number of recommendations have been made, which are being considered in the deliberations of the Undergraduate Curriculum Development Committee.

Several faculty members are currently involved in the ECSEL program. Specific activities under way in this program are projects such as the improvement of the effectiveness of undergraduate engineering education and the attraction of more students to this field. Professors Flowers, Kamm, Mann, Peterson, Simone Hochgreb, Mark Jakiela, Harri Kytömaa, Frank McClintock, Igor Paul, Joseph Smith, Jr., David Gordon Wilson, and Dr. Michael Rosen are contributors to this effort. The engineering-design instructional computer system EDICS continues to grow in popularity and versatility. Interest has been expressed by several mechanical engineering departments around the country in adopting EDICS as a teaching tool.

Faculty have also continued work in the development of the core manufacturing subject. An undergraduate manufacturing textbook has been written, and is being revised at this time. A special summer subject based on the core manufacturing subject has been offered through the American Society of Engineering Education for engineering educators so experience in the manufacturing area can be shared among a number of schools. Over 40 schools sent their faculty members to this program in two years.

The design contest associated with 2.70 Introduction to Design continues to gain national and international attention. The concept has been introduced to Germany, the United Kingdom, Japan, and Korea by Professor Harry West through the International Design Congress, which took place at MIT again this year.

Two new subjects have been added to the curriculum for next year, 2.721 Design for Production, taught by Professors Peterson and Hardt, and 2.971 Independent Activities, taught by Professor Wilson.

Organization

The Undergraduate Program is administered through the Undergraduate Office. The office is supervised by Professors Griffith (Chair, Undergraduate Committee) and Wilson (Undergraduate Officer). Professor Ernest Rabinowicz is the Scheduling Officer. They are responsible for organizing and coordinating the Undergraduate Program and the scheduling and staffing of undergraduate subjects. The Senior class Registration Officer is Professor Griffith, the Junior class Registration Officer is Professor Peterson, and the Sophomore Class Registration Officer is Professor Warren Seering. Professor Thomas Sheridan is the Advisor for Course II-A, and Professor Paul is the advisor for Course II-B. Ms. Peggy Garlick is the Undergraduate Programs Administrator.

Student Organizations

The Student Chapter of the American Society of Mechanical Engineers, under the leadership of its officers Elizabeth Staub, President, Jaime Ramirez, Vice President, Vikram Mehta, Secretary, and Maia Singer, Treasurer, has continued to develop student professional activities in the department. Professor Paul serves as the Faculty Advisor to the 133 members.

Black ME is an organization of students which provides a supportive environment for minorities in the department. Membership continues to be strong with about twenty students. The present leadership comprises Alvin Ramsey, President, Giovanni Gambrell and Mélani Labat, Vice Presidents, Felicia Washington, Secretary, Charisse Russell, Treasurer, and Matthew Phillips, Career Officer. Professor Wilson continues as the Faculty Advisor.

Pi Tau Sigma, the mechanical engineering honorary society, continues its tradition of fostering student-faculty relations and serving the department through its course and instructor evaluations, and honoring newly-elected members with a spring banquet. The organization is led at present by Michael Carnette, President, Katie Broughton, Vice President, Nate Ritter, Corresponding Secretary, John Chow, Recording Secretary, and Jeff Nielson, Treasurer. Professor Derek Rowell serves as Faculty Advisor.

The Student Chapter of the Society of Manufacturing Engineers has as President Suzelle Tardiff. Professor Rabinowicz is the Faculty Advisor.

Graduate Programs

Degrees

The department offers the SM degree in Mechanical Engineering, the undesignated SM degree, the degree of Mechanical Engineer, and the doctoral degree (PhD/ScD) 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 is 422 full-time students. As of the fall term, the enrollment included 52 women and 11 underrepresented minorities from a total of 47 minority students. In September 1991, 224 new students were admitted from 658 applicants, with 137 students registering.

In 1991-92 the department awarded 120 SM degrees (of which 10 were combined SB/SM degrees) and 31 doctoral degrees.

In the fall term, 94 percent of all graduate students received support from the department, MIT funds, fellowships, government, or industry. Of those students, 69 percent were supported by the department through research and teaching assistantships.

Graduate Curriculum Development

Efforts are continuing to develop graduate subjects in the areas of control, manufacturing, and design. The effort for manufacturing education was coordinated with the LFM program. Many students in LFM enroll in subjects in the department in the areas of manufacturing processes, automation, systems, and design for manufacturing.

An innovative new graduate education program, started in September 1991 by faculty in the design area, is developing according to plan. The New Products Program leads to an SM degree in Mechanical Engineering with students taking subjects in both engineering and management. The program is coupled closely to industry with students undertaking the development of new products to learn explicitly about the new product development process.

Three new subjects have been added to the curriculum for next year: 2.63J The Application of Technology, a school-wide elective taught by Professor Deutch; 2.739J Product Development in the Manufacturing Firm, taught by Professor Flowers and professors from Course 15; and 2.785J Mechanical Forces in Organ Development and Remodeling, taught by Professor Ioannis Yannas and Dr. Myron Spector.

Organization

The graduate program is administered through the Graduate Office under the supervision of Professors Ain Sonin (Chair, Graduate Committee and Registration Officer) and Triantaphyllos Akylas (Graduate Admissions Officer). Ms. Leslie Regan is the Graduate Program Administrator.

STUDENT AWARDS

Many students in the department were recognized for academic excellence, engineering creativity, and community service.

Luis de Florez Awards were made to Dong-Chul Choi, Jon Demerly, Stacey Au, and John Kevin Sieh.

The Whitelaw Prize was awarded to Dionne Chapman.
Suzelle Tardiff received the ASME Student Section Service Award.

The Wunsch Foundation Silent Hoist and Crane Awards were given to Chad Clizer, Sima Doshi, Paul Hsiao, Dokyun Kim, Heather Klaubert, Matthew Manning, Geoffrey Mayne, Sandhya Vasan, Chikyung Won, and Elizabeth Zapata.

The Reinhold Rudenberg Memorial Prize was awarded to Tzu-Jun Yen.

Amoco Foundation Scholarships were awarded to Lisa Tegeler, James Page, and Albert Chong.

Jeanne M. Sullivan was the first recipient of the Meredith Kamm Memorial Award.

RESEARCH

Activity Areas and Support Levels

Research in the department varies from very basic, fundamental research to the conception, design, and prototype evaluation of innovative systems to serve the needs of society. The majority of the faculty are explicitly involved in basic research, and almost every research project in the department has a fundamental component. Fundamental disciplinary research is conducted in the areas of mechanics and materials, fluid and thermal sciences, systems and control, and design. The department is also engaged in interdisciplinary research. Collaborative efforts in engineering systems is an important component of the department's commitment to research, since they facilitate the exchange of ideas and foster collaboration across the traditional disciplinary boundaries of engineering. The interdisciplinary Systems Research Groups are: Manufacturing; Energy and Transportation; Living and Environmental Systems; and Information.

A proposal for the establishment of the Biomedical Engineering and Science Center has been made by faculty members in the School of Engineering under the leadership of Professor Kamm interested in interdisciplinary research relating to bioengineering. The center, once approved, is expected to enhance research activities in bioengineering at MIT and in the department.

The department has formed the Manufacturing Institute in the past year. The Manufacturing Institute will provide a direct link between university research and industrial application. It will facilitate the implementation of key advances obtained through basic research. The objective is to establish an environment for rapid, effective and efficient technology transfer to real time production, and at the same time, to provide the department with a "teaching factory," equivalent to the teaching hospitals used by medical schools, to expose students to the problems associated with "scale-up" of discrete mechanical and electromechanical products.

The department's Center for Information-Driven Mechanical Systems, the mission of which is to create new paradigms for interdisciplinary studies, has grown in the last several years, especially in the area of intelligent machines. Further strengthening of the Center has occurred with the formation of the systems research group in the general field of information technology. The new group will provide organization and leadership for future growth in this emerging field.

The volume of sponsored research for the 1991-1992 year administered through the department is $8.5 million, approximately a nine percent increase from the volume last year. Additional sponsored research of an approximately equal amount is administered through interdepartmental laboratories and centers in which department faculty participate. These centers include the Energy Laboratory, the Laboratory for Manufacturing and Productivity, the Materials Processing Center, the Health Sciences and Technology Program, the Leaders for Manufacturing Program, and the Center for Transportation Studies. The department continues to receive strong research support from industry and private foundations, which now accounts for approximately 46 percent of the total departmental research volume. This is a significant achievement of the faculty, especially in view of the increasingly competitive environment for research funding.

Research By Disciplinary Division

Mechanics and Materials

Acoustics: random vibration; rotor dynamics; wideband structural response; nonlinear water wave generation; fluid structure interaction. Computational methodologies: fundamental numerical techniques; nonlinear and fracture analyses. Manufacturing: laser machining; robotics; three-dimensional printing; magnetic levitation; precision engineering; liquid droplet manufacturing; microcellular plastics; scheduling; composites processing and fabrication; friction and wear; Axiomatic design. Mechanics and Materials: theoretical and experimental analyses of metals, polymers, oil, shale, synthetic skin, fibers, and composites; forming, fracture, fatigue, creep, nondestructive evaluations of the above materials.

Thermal and Fluid Sciences

Automotive and Combustion: spark ignition engine operation; engine lubrication; fuel composition to reduce emissions and enhance performance; analytical and diagnostic methods in automobile product development; computational methods for mixing and reactions in complex flows; new engine (e.g. two-stroke cycles) and vehicle technology to improve fuel consumption, noise and emissions; policy strategies for improving urban transportation. Cryogenics and Thermodynamics: development of a superconducting generator; fundamental heat transfer mechanisms during oscillatory fluid flow in Stirling engines; design and development of cryocoolers based on principles such as isothermal expansion and adiabatic demagnetization; heat transfer in microstructures and novel materials such as high-T_c superconductors, diamond, and compound semiconductors; applications to the design of VLSI integrated circuits; design and development of a novel infrared radiation detector combining silicon micromachining with superconducting film technology, and of precision temperature control techniques for thin-film deposition processes. Fluid Mechanics, biomedical: arterial flows and atheroschlerosis; pulmonary flows and respiratory disease; flows in the eye with application to glaucoma. Environmental: electroosmotic decontamination of waste sites; prevention of fouling in membrane water treatment processes. Computational: numerical simulation of complex fields with parallel processing; intelligent databases and expert systems for fluid mechanics knowledge; computational procedures in design; new image enhancement algorithms. Manufacturing and Instrumentation: buildup of physical objects and materials by precise high-frequency deposition of molten microdrops (e.g. 3D xerography); non-invasive diagnostics for dense slurry flows (e.g. coal-water mixtures). Physico-chemical: rheology of dense slurries; properties of macromolecular solutions, with applications in biomedical processes; gas-liquid flows with phase change, with applications in oil drilling, the energy industry, and industrial processing; ocean sedimentation dynamics. Heat and Mass Transfer: design and performance of two-phase flows in steam generators, boilers and condensers; turbulent transition, with application to energy-efficient heat transfer augmentation; thermohydraulic design of containment and safety systems for passively-safe nuclear power systems; design of safe nuclear fuel transportation systems; thermal control of defect-free, melt-grown semiconductors, nonlinear optical crystals, and other electronic materials; jet impingement cooling for extreme power density heat removal; aerosol transport, with application to pollution control, cleanroom design and transport in the lung; fluidized bed systems for clean coal combustors; heat and mass transfer in porous thermal insulation for application to energy-efficient building design.

Systems and Control

Control Theory and Implementation. Nonlinear and adaptive control systems: digital and microprocessor-based control systems; time delay control systems; control-relevant physical systems modeling. Bioengineering and Living Systems: biomechanics and neural control of movement; rehabilitation and medical engineering; man-machine systems and human factors; medical image processing; haptics and virtual environment systems. Robotics: telerobotics; robot control on mobile platforms; robot impedance control; information-driven mechanical systems. Mechanical Systems and Manufacturing: precision mechanical systems control; integrated electro-mechanical systems (Mechatronics); control of manufacturing processes; automated manufacturing; vehicle dynamics.

Design

Computer-Aided Design and Manufacturing: networked computer-aided design, workshop metaphor; computational tools for design of free-form surfaces, mechanical assemblies and tolerances; automated aesthetic design, automated assembly; three-dimensional printing: rapid tooling and prototyping; Engineering Design Instructional Computer System. Design and Design Methods: design methodology; computational tools for design engineers; precision engineering; Axiomatic design; braced manipulators. Biomedical: advanced medical devices; tumor hypothermia; musculoskeletal modeling; computer-based system for the clinical assessment of tremor; biomechanics of head protection.

DEVELOPMENT FUNDS

The department has benefited significantly from a number of donations and grants given by MIT alumni, friends, foundations and industrial organizations. These discretionary funds have been used as seed funds to initiate new research areas, to acquire equipment for education and research, and to enhance new faculty development. Grants from du Pont, Thermo Electron, Alcoa, Ford, General Electric, Cummins Engine, and the Star Foundation have been of considerable assistance to the department. In addition, gifts from private sources such as Mr. and Mrs. Eric Newman, Mr. and Mrs. Neil Pappalardo, Drs. Roger and Gail McCarthy, and Professor Emeritus Rohsenow have been of great assistance. Graduate fellowships honoring Professors Emeriti Frank McClintock, Stephen Crandall, and Nathan Cook have been established in AY 1991-92. Active solicitation for support of these fellowships has been undertaken.

FACULTY AND STAFF

Size and Composition

On September 1, 1991, there were 57 full-time faculty; 31 professors, 18 associate professors (11 with tenure), and 8 assistant professors. The teaching, research, and technical staff fluctuates around 70, more than half of whom are part-time.

Organization and Management

The department is organized in four disciplinary divisions and four Systems Research Groups. The divisions are: Mechanics and Materials (Head, Professor James Williams, Jr.); Thermal and Fluid Sciences (Head, Professor Sonin); Systems and Control (Head, Professor Neville Hogan); and Design (Head, Professor Gossard). The Systems Research Groups are: Manufacturing (Professor Timothy Gutowski); Energy and Transportation (Head, Professor Smith); Living and Environmental Systems (Head, Professor Probstein); and Information (Head, Professor Haruhiko Asada). An ad hoc committee has been established to review this structure.

Accomplishments and Awards

Professor Anuradha Annaswamy was appointed to the George N. Hatsopoulos Career Development Chair in Mechanical Engineering for two years.

Professor Ali Argon recently received a Senior US Scientist Award from the Humbolt Foundation of Germany.

Professor Stanley Backer was elected to the National Academy of Engineering.

Professor Mary Boyce was given a du Pont Faculty Award, renewable for up to three years. She was also appointed du Pont Associate Professor of Mechanical Engineering.

Professor Chun was appointed to the Esther and Harold E. Edgerton Career Development Chair in Mechanical Engineering for two years.

Professor Flik was appointed to the Samuel C. Collins Career Development Chair for three years.

Professor Elias Gytftopoulos has recently published a book entitled *Thermodynamics: Foundations and Applications.*

Professor Heywood was appointed the first Sun Jae Professor of Mechanical Engineering.

Professor Jakiela was appointed to the Robert L. Noyce Career Development Chair in Mechanical Engineering for two years.

Professor John Lienhard V was awarded the Ralph R. Teetor Educational Award by the Society of Automotive Engineers.

Professor Mann was elected a Fellow of the American Institute of Medical and Biological Engineering. He was also awarded a Presidential Citation for Excellence in Establishing the Largest Class-Supported Scholarship at MIT, Class of 1950 Financial Aid Fund, MIT Alumni/ae Association.

Professor Alexander Slocum has recently published a textbook entitled *Precision Machine Design*, and was appointed to the Flowers Career Development Chair in Mechanical Engineering for two years.

Professor Slotine has recently published a textbook entitled *Applied Nonlinear Control.*

Professor Nam Suh has recently published a book entitled *The Principles of Design.*

Professor Williams was appointed as a School of Engineering Professor of Teaching Excellence for five years.

Promotions

Associate Professors Hardt, Parks, Rowell, and Ahmed Ghoniem were promoted to full professor effective July 1, 1992.

Associate Professors Sachs, Slotine, and Kamal Youcef-Toumi were promoted to associate professor with tenure effective July 1, 1992.

Assistant Professors Boyce, Kytömaa, Slocum, and West were promoted to associate professor effective July 1, 1992.

New Faculty

Professor Annaswamy, who received her Ph.D. from Yale University, was appointed as Assistant Professor. Her area of interest is systems and control.

Professor Mark Sylvester, who received his Ph.D. from MIT, was appointed as Assistant Professor His area of interest is mechanics and materials.

Associate Professor Lorna Gibson joined the department as a joint appointment with the Civil Engineering department.

Professor Alan Grodzinsky joined the department as a triple appointment with EECS and HST.

Retirements

Professors Mann and Patrick Leehey retired effective June 30, 1992. They will continue as Whitaker Professor of Biomedical Engineering, Emeritus and Professor of Mechanical Engineering, Emeritus, respectively. They will remain in the department as Senior Lecturers.

Nam P. Suh

Department of Nuclear Engineering

INTRODUCTION

Nuclear Engineering (NED), the youngest department of engineering at MIT, has just finished its thirty-fourth year of existence. Among the notable events was the establishment of the first chair dedicated to nuclear engineering at MIT. The chair, established through a gift from Korea Electric Power Corporation, is a testament to the maturity of the field of nuclear engineering and to the belief by KEPCO and MIT that it is an important one for the future of industrially growing societies. The first chair holder is Professor Neil Todreas. The important role of nuclear power in the twenty-first century was the theme chosen by Dr. D. Allan Bromley, President Bush's science advisor, as he delivered last April the Third David J. Rose Lecture in Nuclear Technology. Confidence in the future of the nuclear engineering profession is shared by the sixteen sophomores and forty new graduate students joining the department this September.

For the third consecutive year the department was ranked the best in the country in the annual survey by *US News and World Report*. To maintain this premier position in the next decade, a long-term planning effort was initiated to guide the department's evolution into the most promising strategic areas.

The department welcomed Visiting Professor Alfred Schneider and Assistant Professor Scott Simonson, who are interested in the areas of nuclear chemical engineering and waste management, as new members of the faculty. Professor Gordon Brownell, whose primary interest is in biomedical applications of radiation, retired at the end of the year. Associate Professor Nathan Siu, whose expertise is in probabilistic risk methodology, leaves MIT to join EG&G Idaho.

ACADEMIC PROGRAM

A revised undergraduate program structure was implemented in September 1991. The new structure allows students to choose one of two optional tracks: "Nuclear Energy" and "Radiation in Medicine and Industry." In the revised structure, there is a significant portion of common elements, as well as a higher degree of emphasis on the integrated design experience.

The development of the undergraduate education continues to be a focus for long-range planning. Professor Ian Hutchinson chaired a departmental committee to explore possible initiatives in undergraduate education. The committee identified "Engineering Physics" as an important area in which departmental strengths and interests could provide additional educational opportunities for students, consistent with a need for disciplinary breadth in a changing society. Discussion of this possibility is continuing.

The NED's Radiation Health Physics program was approved to host DOE Fellowships in Doctoral-level Health Physics. This adds to the already approved DOE fellowship fields of nuclear engineering, fusion science and technology, and civilian waste management.

Professors David Lanning and John Meyer participated in the initial offering of a subject on space power and propulsion. This subject was coordinated by Professor Jack Kerrebrock of the Department of Aeronautics and Astronautics and will continue to be offered as a joint subject, 22.34J Space Power Generation.

The subject 22.76 Nuclear Chemical Engineering was reintroduced and taught by Professors Schneider and Simonson. During IAP 1992, Professor Schneider lectured on "Disposal of Radioactive Wastes — Two Billion Years of Experience."

Another subject, 22.45J Lattice Gas Algorithms and Architectures, was introduced during the spring term by Professor Kim Molvig as a joint subject with Electrical Engineering and Computer Science.

New versions of graduate subjects 22.615 and 22.616 were offered this past year. These subjects merged and reorganized material from three previous subjects. The new subjects are entitled Theory of Plasma Confinement I and II and cover magnetohydrodynamic (MHD) equilibrium and stability and classical plasma transport in a cylinder and a torus.

During the year, the plasma laboratory addition, used for subjects 22.069 and 22.69, was refurbished. This enabled us to start assembling a mini-machine shop to be used by students and faculty. Several experiments were upgraded for the laboratory subject 22.09/22.59 Principles of Nuclear Radiation Measurement and Protection.

The course 22.35 Nuclear Fuel Management has been removed from the schedule. The material covered in this subject will be dispersed through other departmental offerings. Undergraduate subjects 22.062 Fusion Energy II and 22.056 Principles of Medical Imaging were also removed. Both were being offered jointly with graduate subjects that will continue to be offered.

STUDENT ENROLLMENT, HONORS, AND AWARDS

Undergraduate Students

Undergraduate enrollment near the end of the school year was 15 (nine sophomores, three juniors, and three seniors). Seven undergraduate degrees were awarded (one S.B. and six S.B./S.M.'s). Of the seven degrees, two went to women (two S.B./S.M.'s).

A departmental honor was bestowed upon undergraduate Rodrigo Rubiano. Mr. Rubiano was presented with the Roy Axford Award for the Outstanding Senior in Nuclear Engineering. He was one of three senior scholar-athletes chosen by the Institute to receive the Malcolm Kispert Award.

Graduate Students

During the academic year 1991-92, the department enrolled 135 graduate students. The table below gives further details regarding the research interests of NED students.

Research Area	Passed Qual Exam	Pre-Qualifying Exam; Other Degree Programs
Fission	28	25
Fusion	22	16
Radiation Sciences	20	20
Energy	2	2
Total Grad Students	72	63

A total of 50 advanced degrees were awarded by the department this past year. These included 20 doctoral, 3 engineer/master's, 21 master's, and 6 five-year bachelor/master's degrees.

The department's "Outstanding Service Award" to recognize exceptional student contributions to the department, the Institute, and the nuclear engineering profession was awarded to two recipients, Tony Hechanova and Thomas Hsu. Mr. Hechanova was recognized for his exceptional contributions as American Nuclear Society (ANS) Public Information Officer to the ANS High School Speakers Program. Mr. Hsu was recognized for his exceptional contributions towards the science education of high school students; his aid to the department in recruiting graduate students; and his assistance with 22.069/69 Plasma Laboratory experiments.

To recognize their academic achievements, the department presented The Manson Benedict Fellowship for 1992-93 to John Murphy and The Theos Thompson Memorial Fellowship to two incoming graduate students. They are Hernan Trosman from the University of Florida and Brett Mattingly from Clarkson University.

Everett Redmond III received the Sherman Knapp Scholarship for 1991-92, which is funded by Northeast Utilities. Other students receiving fellowship honors during the year included Jonathan Witter, the Space Grant Fellowship; Meijie Tang, the Sir RunRun Shaw Fellowship; and David Cist, a fellowship from the Schlumberger Foundation.

The Institute of Nuclear Power Operations granted the Department of Nuclear Engineering three National Academy for Nuclear Training Fellowships for the 1991-92 academic year. Fellowships in the area of nuclear engineering were presented to David Freed, Philip Hopkins (fall), and Sandra Harms (spring). A third fellowship in the area of health physics was awarded to Jean Marie Moran.

Seven graduate students were awarded Department of Energy (DOE) Fellowships for the academic year 1991-92. Kenneth Crosswait and Daniel Lo received Magnetic Fusion Energy Technology Fellowships. Nuclear Engineering and Health Physics Fellowships were awarded to Jill Broda, Vinh Dang, Tom DeLorey, and Jess Gehin. Mark Sautman, a first-year graduate student, was granted a fellowship in Civilian Radioactive Waste Management.

Robert Kirkwood, a recent doctoral graduate, received the Simon Ramo award of the Plasma Division of the American Physical Society for outstanding doctoral dissertation. His thesis, entitled "Measurement of Suprathermal Electrons by Cyclotron Transmission in the Versator II Tokamak," was supervised by Professor Hutchinson.

American Nuclear Society - MIT Student Branch
The MIT American Nuclear Society Student Branch serves as the focal point for social, athletic, professional, community service, and academic activities conducted by NED undergraduate and graduate students. For the second consecutive year, the MIT ANS Student Branch was awarded the prestigious 1992 Samuel Glasstone Award as the Most Outstanding Student Branch (among a total of 54 in North America) by the ANS national organization. Some of the past year's activities are briefly outlined here.

The ANS organized and hosted a Monday afternoon seminar series that featured 20 guest speakers from a variety of fields in nuclear science and technology. The successful High School Speakers Program was expanded to reach middle schools in the New England area. ANS volunteers donated their time to speak on nuclear technology and environmental issues at over 30 schools during the past year.

On the community level, the ANS organized a Homeless Shelter Soup Kitchen. This monthly event helped provide nourishment for our homeless neighbors. They also established a Food & Sock Drive to help the homeless during the winter.

They have been involved in hosting and planning the ANS National Conference Teachers' Workshop in Boston. In addition to providing exhibits for the 1992 National Science Teachers' Association National Convention, they invented low-cost and easy-to-make experiments for local and national science teachers.

Alpha Nu Sigma Society - Massachusetts Beta Chapter
The Alpha Nu Sigma Society is the national honor society for nuclear science and engineering. Alpha Nu Sigma recognizes outstanding academic achievement by students in nuclear engineering by membership in the Society. Over 30 NED students are actively involved in this Society.

Early this spring, the department and the Alpha Nu Sigma Society co-sponsored the 1992 David J. Rose Lectureship of Dr. Bromley on the subject "Nuclear Power for the 21st Century." His presentation was well received by faculty, staff, and students from various disciplines.

This past year the MIT Chapter planned and hosted two special dinners to discuss the role of teaching at a research university, one in each term. The chapter also undertook mid-term evaluations of all department subjects.

RESEARCH PROGRAM

Fission
The Advanced Nuclear Power Reactor Studies Program continues under the direction of Professor Michael Golay. His research projects include a comparison of active and passive design approaches to nuclear reactor safety. He, Professor Schneider, and Dr. Marvin Miller investigate environmental impacts of the combined LWR and LMR fuel cycles. Professors Golay and Mujid Kazimi have continued their studies of condensing heat transfer in steam-gas mixtures.

In the area of Modular High Temperature Reactors (MHTGR), work is coordinated by Professor Lawrence Lidsky. Research continues on the assessment of the passive safety features, of potential fission product plateout and release in the helium-cooled system, and of the direct cycle (gas turbine) and indirect (steam cycle) power plant design and operation.

Professor Todreas and Dr. Michael Driscoll (professor emeritus) have continued their research on decay heat removal by passive means through three investigations. The first project is a fundamental investigation of heat

transfer and friction under low flow conditions in naturally circulating air ducts. The second investigates such air chimneys, now a feature of many advanced reactor designs, as they are applied to the modular high temperature gas reactor. The third project is the development of a light water cooled reactor concept that can passively remove decay heat under the constraining assumption of unavailability of emergency makeup coolant. These concepts involve the use of a solid matrix containing fuel inside pressure tubes within a low pressure calandria tank. Decay heat is removed by a naturally circulating light water calandria system, which forms a thin cooling annulus around each pressure tube.

Advanced instrumentation and control and space nuclear power studies are both being coordinated by Professor Lanning. Other supervisory members of the group include Professors Meyer and Allan Henry and Dr. John Bernard. The advanced instrumentation and control research involves investigation of the use of state-of-the-art methods in reactor physics and thermal hydraulics to develop digital computer-based models for use in real time information and control systems. This research area has attracted excellent students and has been sponsored in part through various DOE funding agencies. In the space nuclear power and propulsion area, the emphasis is also on methods and models as well as control. Again, there is a high student interest, but in this case the research has been primarily unsponsored. The researchers are expecting some funding through Brookhaven National Laboratory and NASA.

The International Program on Enhanced Nuclear Power Plant Safety completed its second full year of operation under the direction of Professor Kent Hansen. The program has active projects in the areas of nuclear plant management, the impacts of social policies on plant safety, and the technology of service/maintenance to reduce risks. The program is sponsored by an international consortium of utilities, vendors, and suppliers. The program is centered in the Department of Nuclear Engineering and the Energy Laboratory with participants from six other departments and laboratories.

A new, multi-year, large-scale program on improving the environmental management of DOE nuclear waste began this year under the co-direction of Professor Hansen and Dr. Malcolm Weiss of the Energy Laboratory. The program is modeled after the International Program on Enhanced Nuclear Power Plant Safety and includes research in the management, technology, and policy areas. The focus of the program is to provide the DOE with new insights into the issues involved in successfully managing the operations and restoration of nuclear weapons sites. The program is collaborative with the Los Alamos National Laboratory.

Study in the area of reactor safety, reliability analysis, and risk assessment is conducted by Professor Norman Rasmussen and Professor Siu. Work continued on the development of a simulation model treating the interactions among operating crew members during a nuclear power plant accident. The model has been benchmarked against the performances of real operating crews during training exercises. Current efforts are focused on expanding the model to treat major errors in cognition. Another project investigates the risk impact of maintenance program changes when different elements in a maintenance program are varied. Efforts concentrated on determining the effect on common cause failure rates and human error rates. In applying the work towards an actual power plant, it was shown that a much more stringent maintenance program could strongly affect these failure rates, but would only reduce risk by around a factor of two, due to the presence of other risk contributors.

Professor Otto Harling and Dr. Driscoll continued their successful program of PWR and BWR in-pile loop tests. These tests use unique facilities which closely model the in-core environment of PWR and BWR power reactors to study dose and corrosion reduction through optimized water chemistry. Professors Harling and Ronald Ballinger are studying irradiation assisted stress corrosion cracking in high strength alloys used in BWRs. This work includes the development of a unique in-pile autoclave with a slow strain testing system. To perform some of these studies a state-of-the-art Scanning Electron Microscope facility was established.

Professor Todreas has continued with thermal analysis of spent fuel under dry storage or shipping conditions. An accurate but simple effective thermal conductivity method has been developed to compute the maximum clad temperature within the fuel bundle. This method developed for commercial light water fuel assemblies is now being extended to fast reactor hexagonal fuel bundles. These bundles are moved within the reactor fuel cycle facility where they are reprocessed and reconstituted into new fuel for reinsertion into the fast breeder reactor concept.

Professor Meyer completed a project (Narrow Channel Turbulence Modeling) for Oak Ridge National Laboratory. This project is part of an effort to establish the minimum blockage size for the advanced neutron source reactor

(ANSR) that would cause fuel element damage. The work is aimed at turbulence modeling of the heated flow of water through a single ANSR coolant channel, using the FLUENT computational fluid dynamics (CFD) software.

In the area of reactor physics modeling, Professor Henry and his students have continued work on the development of nodal methods for the prediction of static and transient neutron behavior in reactors. In these methods, large, heterogeneous subregions (nodes) of the reactor are homogenized, and the transverse integrated fluxes within such regions are represented by polynomial expansions. Errors arising from the homogenization procedure or due to a low order of expansion are corrected by "discontinuity factors" determined from auxiliary calculations. Recent achievements have been the development of transient nodal codes incorporating thermal-hydraulic feedback in XYZ, RZ and Hex-Z geometries. In addition, to speed the solution of transient problems, high order time-differencing methods and automatic time step selection schemes have been explored.

Research related to the options for relicensing the MIT Research Reactor has been initiated. The relicensing is required in 1996, and the review of the major redesign or upgrade options must be made within this next year or so in order to make a timely choice and a final design for the relicensing application. Initial funding from MIT has been approved for this study and a proposal has been sent to the Department of Energy for the required funds to carry out this study on future uses, design options, and cost-benefit comparisons. The work involves student thesis research projects supervised by appropriate faculty in the department, including Professors Henry, Meyer, Lidsky, Jacquelyn Yanch, Todreas, and Kazimi and Dr. Driscoll, as well as the members of the Nuclear Reactor Laboratory staff, including Drs. Bernard and Kwan Kwok. The project is being coordinated by Professors Lanning and Harling, who will also be supervising student theses in this area and guiding the integration of the information from the various design studies.

Fusion

Fusion research is conducted primarily at the Plasma Fusion Center. NED faculty affiliated with this center include Professors Ballinger, Jeffrey Freidberg, Hutchinson, Kazimi, Meyer, and Molvig.

Professor Freidberg continued his research on alpha particle Alfven gap modes in collaboration with former NED doctoral student, Riccardo Betti, now an assistant professor at the University of Rochester. Professor Freidberg has also continued his transition from plasma physics to plasma engineering in recognition of the future direction of the fusion program. In this connection, he is involved in studies of fast poloidal field solvers including self-consistent current profile evolution. The corresponding computational module has been incorporated into the "SuperCode" — a 1-1/2 D plasma engineering systems code now being used by the fusion community to design next generation tokamak experiments. In fact, almost the entire plasma physics model in the SuperCode was developed through the thesis work of several NED graduate students. Professor Freidberg is also involved in developing simple but realistic models for studying quench protection in superconducting magnets.

Professor Hutchinson heads the Alcator research project whose new tokamak experiment, Alcator C-Mod, began operation in October 1991. This major experiment will provide vital physics and plasma engineering information for the design of burning fusion plasma experiments. The Alcator project currently supports ten NED students with research assistantships on projects ranging from building frozen hydrogen pellet injectors to developing fast feedback control systems for tokamaks.

Professors Kazimi and Meyer expanded their studies of water-cooled solid surface divertors. They have also proposed new approaches to divertor design based on a liquid-metal droplet concept on a high speed gas jet concept. The divertor is an important element in the development of tokamak reactors with high energy density. Professor Ballinger continued his investigation of the materials aspects of high field magnets and superconducting magnet development.

Radiation Science and Technology

Research within the Radiation Science and Technology area is being conducted by Professors Brownell, Sow-Hsin Chen, Harling, Yanch, and Sidney Yip. Professors Harling and Yanch and their colleagues at the New England Medical Center are making steady progress in the development of neutron capture therapy for refractory tumors. An epithermal beam suited for treatment at any location in the human brain and a series of successful animal experiments have contributed to major progress in the last year.

Detailed dosimetric calculations of the dose delivery profiles from 252-Californium implants in the brain and other tissues have been performed by Professor Yanch and Dr. Robert Zamenhof of the Tufts-New England Medical

Center. Professor Yanch and Dr. Andrew Dobrzeniecki, a research associate, have undertaken a computer simulation study of nuclear medicine imaging for image quantification. These investigations will ultimately lead to development of new methods to improve the quantitative information available in nuclear medicine tomographic images.

Additional research efforts of Professor Yanch include a study of the effects of radon on human genetic material, and the use of beta-emitters in the treatment of rheumatoid arthritis. Professors Yanch and Brownell are also involved in a three-year collaboration to develop an epithermal neutron source using a new type of ion accelerator.

Professor Brownell and his students developed PCR-II, a PET system with 3 mm resolution. A micro-tomograph design with 1 mm resolution for small animals has also been developed.

In the area of applied radiation physics, Professor Chen and his students have discovered an oscillating surface structure of bicontinuous microemulsions using newly developed neutron specular reflectivity technique.

Professor Yip continued studies focusing on two problems, the fundamental nature of glass transition, and the structure and mechanical behavior of interface materials, in both cases using a combined approach based on atomistic simulation and condensed matter theory. Colleagues from several engineering departments are also participating in these research projects.

In the area of nuclear waste technology and environmental control, Professor Simonson has initiated work in two areas. The first is the development of novel methods to experimentally measure the behavior of radioactive waste (principally uranium) in unsaturated soils and rocks. The second involves developing models that describe source terms for the gaseous release of radionuclides from low-level wastes. Additionally, he is setting up a laboratory to measure radiation effects on aqueous chemistry and its consequences on materials performance (corrosion, cracking, and chemical speciation) with application to nuclear waste storage and nuclear reactor coolant chemistry.

Energy Systems and Policy

Research in the area of energy economics and policy is conducted by Professor Richard Lester and Dr. Miller. Dr. Miller's research focuses on the threat posed by the proliferation of nuclear weapons. Current activities include a project on the feasibility of nuclear arms control in the Middle East, research on options for eliminating nuclear material from retired nuclear weapons, and a study on the proliferation implications of the Integral Fast Reactor.

Professor Lester has been studying the impact of independent power producers on the financing of energy projects.

FACULTY ACTIVITIES AND HONORS

Professor Chen was invited to be a visiting professor in the physics department at the University of Bordeaux I during July and August 1991. Professor Chen, J. S. Huang, and P. Tartaglia edited *Structure and Dynamics of Strongly Interacting Colloids and Supramolecular Aggregates in Solution*, NATO ASI Series 369, Kluwer Academic Publishers.

Professor Golay was an invited lecturer for a special course on nuclear reactors held at the University of Valencia, in Spain. He was also invited to speak at the Canadian Nuclear Society Meeting. He was a member of a preparatory committee for the IAEA Conference on Safety of Nuclear Reactors. For the Boston ANS national meeting, he organized an invited session on advanced reactors. He chairs the School of Engineering's Committee on Open Large Scale Systems.

Professor Elias Gyftopoulos received the American Nuclear Society Student Branch Outstanding Professor Award for the academic year 1991-92. He was the keynote speaker at the thirtieth anniversary celebration of the Nuclear Research Center "Demokritos" in Athens, Greece. He was the commencement speaker at the tenth anniversary of the American College of Higher Studies in Salonika, Greece. He also delivered the keynote address on "Energy Policy" at the 1991 Whitney Symposium on Science and Technology XII on "Energy: Generation, Conservation and Use," at the General Electric Corporate R&D Center in Schenectady, New York.

Professor Harling co-organized a major international workshop on macro and micro dosimetry and treatment planning for neutron capture therapy. At the Boston ANS national meeting, he presented invited papers on neutron capture therapy and on the future mission of research reactors.

Professor Henry received the Technical Achievement Award from the Mathematics and Computation Division and Reactor Physics Division of the ANS. He is a member of the Editorial Review Board of *Nuclear Science and Engineering* and a member of the Program Committee of the Mathematics and Computation Division. Besides serving as departmental CGSP representative, Professor Henry holds membership on the Institute's Advisory Committee on Shareholder Responsibility.

Professor Hutchinson was appointed to the editorial board of *Plasma Physics and Controlled Fusion.* He continued as associate editor of *Physics of Fluids B, Plasma Physics.* He served on the Fusion Energy Advisory Committee's panel on new initiatives.

Professor Kazimi is chairman of the High Level Waste Tank Advisory Panel for the DOE. He is a member of the Oversight Board of Independent Engineering Assessments of DOE and a National Academy Panel on Separations Technology and Transmutation Systems. He also serves as a member of the Visiting Committee of the Fusion Technology Program at Argonne National Laboratory.

Professor Lanning continued as a member of the Safety Audit Committee for the Monticello Nuclear Generating Plant operated by the Northern States Power Company. He also served as a co-chairman of the NSF-sponsored panel to assess European nuclear controls and instrumentation, which published its final report in December 1991.

Dr. Miller organized a US-Israeli Workshop on Arms Control in the Middle East, that was held last February at the American Academy of Arts and Sciences in Cambridge.

Professor Rasmussen was awarded the Ruth and Joel Spira Award for teaching excellence by the School of Engineering. He was appointed chairman of a National Research Council panel on waste disposal technologies called STATS, Separation Technology and Transmutation Studies. He serves as department representative on the School of Engineering's Committee on the Recruitment of Women and Underrepresented Minorities.

Professor Schneider served on the US Secretary of Energy's advisory board task force on radioactive waste and on the Westinghouse Nuclear Safety and Environmental Oversight Committee for all government-owned sites. He continued as an advisor to the New York State Energy Research and Development Authority.

Professor Siu was a member of the Technical Program Committee for the Nuclear Reactor Safety Division of the American Nuclear Society, and was in charge of coordinating special sessions for the national meetings. He also served on the technical program committees for ANS topical meetings on risk assessment and risk management, and is a co-organizer for a NATO Advanced Research Workshop on Reliability and Safety Assessment of Dynamic Process Systems.

Professor Todreas was named KEPCO Professor in Nuclear Engineering, effective July 1992. He continues to serve on the Institute of Nuclear Power's Advisory Committee and the Nuclear Regulatory Research Review Committee. He also served on EPRI's severe accident code, MAAP, review group and its accident management program's technical review committee. While on sabbatical, Professor Todreas was a visiting professor at the University of Hong Kong.

Professor Yanch will receive the W. M. Keck Career Development Chair in Biomedical Engineering, effective July 1, 1992. She will retain this chair for a period of three years. Last October she was a panel member of the MIT Colloquium, "Teaching Within a Research University." She was a member of the Review Panel for the DOE fellowship program in nuclear engineering and health physics.

Professor Yip delivered the Richard Osborn Memorial Lecture at the Department of Nuclear Engineering, University of Michigan, last October. He serves on the editorial board of *Simulation and Modeling in Materials Science and Engineering*, a new journal published by the Institute of Physics, United Kingdom. He gave an invited lecture at the Institute for Fundamental Theory, University of Florida. He also lectured on physics of materials at the Research Science Institute, a summer program for gifted high-school students held at MIT for the first time this year. The Dover edition of *Molecular Hydrodynamics*, his book with J. P. Boon, was published in January.

MUJID S. KAZIMI

Department of Ocean Engineering

INTRODUCTION

The 99th year of the Ocean Engineering Department has just ended. Now that we have started our centennial year, we will celebrate. The highlight will come in June 1993, when ocean engineering will be the focus of Technology Day during the MIT alumni reunions.

Rather than look back, however, we prefer to focus on the future. During most of our first century, our activities in both teaching and research centered on ships and shipping. No one doubts that marine transportation and maritime defense will continue to be prominent in our programs, just as they will be on the world scene. But ocean engineering is simultaneously expanding rapidly in totally new directions.

Much of the new activity in ocean engineering will relate to the ocean depths. Traditionally, our view of the ocean has been a two-dimensional one, but new ocean challenges will require engineers to develop systems to operate in the third dimension as well. The extraction of ocean resources, the monitoring of global climate, and the prevention of pollution (possibly in association with the active use of the ocean for waste disposal) will all require new engineering capabilities that will be as daunting as those required for venturing into outer space. The most obvious difficulty is the water pressure with which one must contend; the hydrostatic pressure at the *mean* depth of the ocean is almost 400 atmospheres. But other difficulties are even more challenging, because they require totally new technologies to be developed. Perhaps foremost among these is the opacity of ocean water to electromagnetic waves, which prevents the use of conventional means of sensing, communicating, and navigating.

A substantial part of our current research is devoted to the development of new technologies for deep-sea engineering for the future. The education of ocean engineers for the future requires an even more distant horizon, for we must provide the educational foundation on which 50-year careers can be built. When we start our second century, we expect to have in place a completely new undergraduate curriculum that will do just that; some detail is provided in the following section.

Even our traditional areas are changing. During its entire history, the Department has supported the US Navy in its fundamental business of designing and building the ships and submarines needed for national defense. Now the long-term reasons for the existence of the fleet are unclear; the nation has entered a period of change in its international relationships as great as any in history. The officers who are now studying naval construction and engineering at MIT will eventually be responsible for the design and building of ships that will still be in service 50 years from now. We do not know what kinds of ships they will be, and so we must educate our students in such a way that they can respond to unknown future defense requirements.

Regardless of the condition of the US maritime industry, world commerce will continue to depend on ships for the transport of most goods and materials. The efficient and safe operation of the international shipping industry will require new technologies, new system concepts, and new management and organizational practices. The Department's well-established strengths in these areas will remain important to the world community, even as the Department works to develop capabilities appropriate to the new problems of ocean engineering.

UNDERGRADUATE EDUCATION

New Ocean Engineering (OE) Curriculum. Last year, we reported on a preliminary study of the OE curriculum by a committee chaired by Professor Ira Dyer. Three foci of the committee's report were noted:

- the lack of a consensus in the Department on the definition of *ocean engineering*,
- the immediate need for an undergraduate subject on physical oceanography for engineers, and
- inadequate undergraduate OE enrollment.

Last year, the Department did indeed reach a general (if not quite unanimous) consensus on the definition of ocean engineering, and it agreed on the overall structure and content of a relevant undergraduate curriculum. At the time the

Dyer committee was meeting, first steps had already been taken to rectify the lack of an undergraduate subject on physical oceanography, and further progress is being made. Several *ad hoc* committees are working on ways to build up the enrollment. A brief description of these activities is presented here. Details are available in a white paper written by the Department Head in December.

For purposes of developing a curriculum, ocean engineering was defined primarily in terms of its fundamental disciplines. The following list of disciplines was accepted by the Department:

- hydrodynamics and oceanography
- structures and materials
- dynamics and wave propagation
- mathematics and computation
- design, applications, and experience

It was decided that subjects should be offered in each area at several levels, basic, intermediate, and advanced, with a common core at the basic and intermediate levels required of all undergraduates in the Department. A list of such subjects was actually created, discussed, and accepted. Short syllabi were developed, and work is proceeding on more detailed syllabi, so that the new curriculum can be phased in starting in 1993-94. Associate Professor Paul D. Sclavounos coordinated these developments during the critical period in the spring.

In view of the small undergraduate enrollment in the Ocean Engineering Department, the faculty agreed that only one degree program should be offered at the S.B. level. The longstanding program in naval architecture and marine engineering (NA&ME) will be suspended and all efforts focused on the OE program. Graduate programs in NA&ME, however, will be continued and even strengthened.

The Department's first action to fill the instructional hiatus in physical oceanography was made in conjunction with the initial offering three years ago of 13.010 Introduction to Ocean Science and Technology I, described in some detail a year ago. (Also, see below under STUDENT PROJECTS.) That subject contains three modules, one of them on oceanography. The first two times the subject was offered, that module was taught by Dr. Wayne R. Geyer of the Woods Hole Oceanographic Institution (WHOI); in the fall term of 1991, it was taught by an OE faculty member. The new curriculum calls for a considerable expansion of teaching in this area, which should come on line in the 1993-94 academic year.

To address the issues involved in attracting more students to ocean engineering, five special committees were created, with charges in the following areas:

- increasing undergraduate enrollment
- career paths for OE graduates
- joint programs with sea-going organizations
- unstructured problem solving
- new IAP (Independent Activities Period) activities

Professor Justin E. Kerwin, as chairman of the first, is coordinating the work of all five committees. Their tasks are open-ended, and these committees will continue to function indefinitely. During the spring, a survey was made of current MIT undergraduates to determine what they know (if anything) about ocean engineering. Developing and presenting information about career opportunities in ocean engineering will be critical to attracting students. Sea-going experience may be very alluring to some students. IAP offers possibilities for making ocean engineering better known among MIT undergraduates. All of these approaches may contribute to increasing our undergraduate enrollment.

With the idea that getting students halfway into ocean engineering is better than not getting them at all, the faculty is seriously considering the possibility of offering a minor in ocean engineering. A general proposal to permit minors is, of course, being discussed elsewhere within MIT. It just might serve the purposes of the Ocean Engineering Department very well.

GRADUATE EDUCATION

New doctoral examinations. The major event of the year relating to graduate education was a complete restructuring of Part I of the doctoral qualifying examination, which was accomplished during the fall term under the leadership of Professor Sclavounos. Since this examination is the most significant hurdle for students aspiring to a doctorate in any of the Department's programs, faculty members were concerned that it measure as well as possible (and as fairly as possible) a student's potential success in achieving a doctoral degree. Scientific staff of the WHOI were fully involved in all stages of the Department's deliberations.

Henceforth, the Part I examination for students in Courses XIII, XIII-B (Ocean Systems Management), and XIII-W (MIT/WHOI Joint Program in Oceanographic Engineering) will consist of three parts:

- written examinations in three areas, mechanics, fluids, and calculus, all required,
- oral examinations in two areas, selected by the student from among acoustics, structures, dynamics and vibrations, hydrodynamics, geophysical fluid dynamics, probability, and signals and systems, or, for students in Course XIII-B, from among management, economics, policy analysis, and legal aspects of ocean systems;
- an oral presentation on a research topic of the student's choice.

The faculty agreed that the Part I examination would be offered only once a year and that students would normally be limited to one attempt. Students already in the doctoral program have the choice of being examined under either the old or the new rules. Thus it was necessary to offer parallel sets of examinations in January and again in May. The Department will continue this complicated process until currently registered students have passed through this part of the system or until no one requests to be examined under the old rules.

As part of the process of changing the examination format, several public meetings were held with students. Student concerns were addressed as fully as possible. In general, not only faculty but also students seem to prefer the new system. A more detailed description of the new rules will be contained in the 1992-93 edition of the *Ocean Engineering Student Handbook.*

Thesis and Project Topics in Course XIII-A, Naval Construction and Engineering. During his three years at MIT, Associate Professor Richard C. Celotto, CDR, USN, devoted special effort to encouraging military students to undertake theses and design projects on topics that are relevant to the needs of their services. His initiative in this respect gives strong support to the Department's general objective in Course XIII-A of integrating education and research aspects of the students' MIT experience. Since almost all theses are supervised, however, by MIT faculty other than the resident USN officers, this undertaking requires that relationships be identified between diverse ongoing research programs and service needs. The success of this effort is indicated by the fact that about three-fourths of all XIII-A theses in the last two years do indeed relate directly to Navy and Coast Guard needs. Professor Celotto's parallel assignment to the Naval Sea Systems Command has greatly helped him accomplish this. (See section below FACULTY AND RESEARCH STAFF.)

SHORT COURSES

Professional Summer Program (PSP). Last year marked the 20th offering of the PSP in collaboration with the Draper Laboratory. It consists of eight weeks of short courses that complement the regular program of Course XIII-A, *Naval Construction and Engineering*; the courses are also available to qualified non-MIT students. The PSP has long consisted of two groups of one- or two-week courses:

Submarines
- Observables, Survivability, and Control
- Design Trends (two weeks)
- Combat Systems

Surface Ships
- Combat System Engineering (two weeks)
- Survivability and Observables
- Combat System Design Integration

In August, the Department offered for the first time an additional one-week course, *Advanced Ship Production*, taught by Professor Howard M. Bunch of The University of Michigan, who has also been a Lecturer at MIT for several years. It drew a capacity enrollment, and it will be offered again this year, with the addition of two more lecturers.

STUDENT PROJECTS

Ocean Science and Technology Class Project. For several years, the Department has offered an elementary subject, 13.010 Introduction to Ocean Science and Technology I, open to all MIT undergraduates, in which a first acquaintance can be made with some of the disciplines that are fundamental to science and engineering in the ocean (physical oceanography, surface waves, and ocean acoustics). This subject has no prerequisites beyond some of the General Institute Requirements, and it qualifies as a Science Distribution subject. The follow-on subject, 13.011 Introduction to Ocean Science and Technology II, provides an opportunity for students to participate in an actual at-sea experiment. It was first offered in 1991, and an account of the tribulations and ultimate general success of the subject was provided in the Department's report a year ago.

Last spring, a project was undertaken to locate some of the hazardous waste that litters the bottom of Boston Harbor. This was motivated by news reports last year that the captain who had been licensed for many years to dispose of capsules of hazardous wastes in a specified area near Boston had not been fussy about where he dumped the containers. Neither he nor anyone else really knew where the wastes were. In the 13.011 project, the plan was to determine the sidescan-sonar signature of a typical container and then, time permitting, do actual surveys of some suspected dump sites. The first part was completely successful: Using a concrete casket as a target (similar to the containers used for low-level radioactive wastes), the students obtained distinctive signatures. The second part was not successful, because of bad weather that made it impossible to use sidescan sonar (and probably would have made everyone sick). The project was nevertheless considered a success by the students and by the Commonwealth of Massachusetts, which has an obvious interest in the enterprise. The students want to try again in the fall - even on their own time. Professor Jerome H. Milgram, who is in charge of the course, is arranging for them to have that opportunity.

Course XIII-A (Naval Construction and Engineering) Projects. Three students in the Naval Construction and Engineering Course (XIII-A) won an award from the Society of Naval Architects and Marine Engineers for the *best graduate-student paper of the year* for their report on their 1991 design of a convertible container/roll-on-roll-off ship. Their project also won the design competition for 1991 in the Ocean Engineering Division of the American Society of Mechanical Engineers. The student team comprised LT Edward N. Ingles, LT David J. Kowalick, and LT Timothy L. McKenney, all active-duty officers in the US Navy. Their work was supervised by Professor Randolph M. Brooks, CAPT, USN, and Professor Celotto.

Last year, students in Course XIII-A undertook major projects to design

- a small special-warfare submarine for shallow-water operations,
- an affordable, reconfigurable submarine to complement the USS SEAWOLF in the new naval strategy, and
- a light frigate, as an affordable ship for use in littoral-area contingency and low-intensity operations.

These projects were also supervised by Professors Brooks and Celotto.

FACILITIES

Ocean Engineering Test Facility. Under the direction of Professor Michael S. Triantafyllou, this laboratory continues to be upgraded. The latest addition is a *digital particle image velocimetry* (DPIV) system, in which a laser beam creates a sheet of light in water seeded with special, small diameter particles; a high-speed camera obtains sequences of pictures, which are digitized through a frame grabber, and then processed to provide quantitative information about the velocity field.

Marine Computation and Instrumentation Laboratory. As reported last year, this laboratory, directed by Professor Milgram, was moved to a new, larger location, Room 1-225. During the past year, the most spectacular enterprise was the installation of a wave tank, which had to be brought into the laboratory through a window on the Massachusetts Avenue side. As it was filled with water, the deflection of the floor was carefully monitored by an outside engineering consultant to ensure that the venerable building could support 40 tons of water on its second floor. (Final deflections were less than one-tenth of what had been anticipated by MIT engineers.) Plans are now being made to equip the new tank for use in acoustics experiments; this would be a joint enterprise between Professor Milgram and Assistant Professor J. Robert Fricke.

AMERICA'S CUP

Since the news media covered the 1992 America's Cup race extensively, it is well known, even by the general public, that the winner, *America*^{3}, was sponsored by an MIT alumnus, Dr. William I. Koch. It has also been widely recognized that this was a race that was won by technology. Much of the new technology was produced at MIT under the leadership of Professor Milgram.

Sailing is an ancient art, and it has remained mostly an art. Surprisingly little has been learned about how to predict the performance of a sailing vessel accurately. In addition to all the hydrodynamic phenomena that affect the performance of a non-sailing ship, there are additional major complications in the sailboat case. For example, the sail is a deformable airfoil; since its shape is never known precisely, the actual wind forces on the boat cannot be calculated by the usual methods of aerodynamics. The effective incident-wind angle varies with height, a result of the natural gradient of wind speed and the forward motion of the boat. The wind force generally has a large sideways component, which must be offset by an opposing sideways force on the keel. The combined action of the sail and the keel cause the boat to heel over and yaw, both of which greatly increase drag and reduce speed.

In the 1970s, Professors Justin E. Kerwin and J. Nicholas Newman developed a Velocity Prediction Program (VPP) for computing the performance of sailing vessels. Similar programs are now widely used to compare competing designs, and it is fair to claim that they have revolutionized yacht design and the making of handicap rules. They require, however, that empirical test data be available for various coefficients, and they provide no answers with respect to the wind-related ambiguities.

Professor Milgram directly and effectively addressed this challenge. First he developed a sail dynamometer. It is an actual sailboat with a 40%-scale America's Cup rig, in which the sail system is completely isolated from the hull through a six-component dynamometer. For the first time ever, the net force and moment of the wind on a hull could be measured.

He also developed a method for obtaining sail shape nearly instantaneously through computer analysis of video observations made from an accompanying vessel. The resulting data can then be used in aerodynamic calculations for comparison with data from the sail dynamometer.

The measured drag must be further decomposed into induced drag and form (or friction) drag. This is necessary because the two follow different scaling laws. Induced drag is determined by methods of computational fluid dynamics (CFD), and the remainder is the form drag. Proprietary computer codes were obtained for computing lift and induced drag.

Towing-tank measurements on sailboats are much more difficult than on ships, since (i) tests must be conducted over ranges of heel and yaw angles, (ii) side force must be accurately measured, and (iii) the allowable errors are about an order of magnitude smaller than for ships. (Variability in test results typically leads to prediction errors of about 0.03 knots. This might correspond to a 25-second margin in a 90-minute race, which might well represent the difference between winning and losing.) New techniques of testing and data analysis were developed for coping with these requirements. The effect of towing-carriage vibration on side-force measurements was a special problem.

Much of this technology was brought together to produce new sail designs. In particular, the new International America's Class uses types of downwind sails that had never been used before. *America*^{3} ultimately had the best asymmetrical broad-reaching sails of any team in the race, which became a major factor in its success.

Results of the MIT research are available in S.M. theses by Mr. Drew Friedes, Mr. Donald Peters, and Mr. Alexis Mantzaris. Mr. D. Noah Eckhouse, a research specialist in the Department, also made major contributions.

BOOKS

Intermodal Movement of Marine Containers, by Associate Professor Henry S. Marcus, has been accepted for publication and is in press. This is Professor Marcus's sixth book.

RESEARCH

Autonomous Underwater Vehicles (AUVs): In collaboration with the MIT Sea Grant (SG) College Program, the Department has undertaken a broad program in the development of autonomous underwater vehicles. Professor Chryssostomos Chryssostomidis, as SG Director, is coordinating this effort. Under his direction, three vehicles have been designed and are in various stages of construction or use:

- *Sea Squirt*, first vehicle in the series, which served as a learning experience for everything that follows,
- *Sea Scout*, to be deployed in the Arctic, and
- *Odyssey*, to be capable of going down to 6000 meters (and returning).

Sea Scout already has a scientific mission, to obtain images of the underside of the ice in Arctic regions. It will be used in a field experiment in the Arctic in 1994, with Associate Professor Henrik Schmidt as Principal Investigator. The immediate purpose of the experiment is to investigate the mechanisms of ice cracking (which is closely related to the ambient noise field in the water). Some knowledge of the morphology of sea ice is important to that study, but obtaining data under the ice has been impossible in the past unless a fleet submarine could be used (an unlikely situation). For use with *Sea Scout*, Professor Schmidt is developing an acoustic navigation system. Assistant Professor J. Robert Fricke has been working on the specifications for the imaging system, which will be based on an existing submarine-based side-scan sonar.

Professor Chryssostomidis, the SG staff, and students are now building *Odyssey*. The pressure hull will consist of two glass spheres that can withstand the hydrostatic pressure at 6000 meters (600 atmospheres); they are available commercially at a cost of a few hundred dollars each, which should qualify them as the least expensive deep-diving pressure hulls ever developed.

Associate Professor Nicholas M. Patrikalakis, who has been developing computer-based geometrical modeling methodologies for several years, is applying that expertise to the problems of navigation in the ocean deep. He is also working on a marriage of underwater sensing systems and 3-D mapmaking.

Other aspects of AUV systems are being investigated by Professor Michael S. Triantafyllou (multiple-vehicle systems), Professor Marcia K. McNutt of the Earth, Atmosphere, and Planetary Sciences Department (magnetic measurements), and Professor Stephen D. Senturia of the Electrical Engineering and Computer Science Department (microsensors).

Arctic Ice Thickness and Global Warming: Last year, we reported on an experiment by Professor Arthur B. Baggeroer and several associates to determine whether a global mean ocean temperature could be found from variations in the transit time of sound waves traveling half-way around the world. (They showed that transit time could be measured to the necessary precision; it has not yet been demonstrated whether such measurements will be able to support any broad conclusions about global climate change.) Professor Fricke has proposed a complementary approach to monitoring global temperature change through the measurement of Arctic ice thickness. The annual rate of increase or decrease of ice thickness in polar ice packs is closely related to the mean annual temperature in those regions. A measurement of polar ice thickness should be a more immediate indicator of global change than measurements of acoustic propagation speed, since the rate of change of ice mass depends directly on mean surface temperature, whereas acoustic transit times depend on temperatures in the sound channel (typically more than 1000 meters deep), where temperature changes lag those in the atmosphere by years.

In his doctoral thesis, Professor Fricke developed (for quite different purposes) a fundamental tool that may help to accomplish this, namely, an acoustic/elastic modeling algorithm for wave propagation through heterogeneous material of arbitrary geometric complexity. Simulations with this model indicate that large, young pressure ridges dominate long-range propagation loss in the Arctic in the frequency band from 10 to 100 Hz. *In situ* measurements of propagation loss in the Arctic should thus yield an estimate of average ridge size, which in turn can provide an estimate of ice mass.

To determine whether this is possible, Professor Fricke is planning experiments in an acoustic-tank test facility to verify the algorithm. If the laboratory experiments produce positive results, the next step will be to conduct experiments in the Arctic. Propagation-loss tests would complement the ice-bottom morphology experiments that will be undertaken with an AUV in 1994 (see preceding description of the MIT AUV research program, in which Professor Fricke is a major participant).

Fish Propulsion. Fluid dynamicists and ichthyologists alike have long been intrigued by the ability of some species of fish to swim with incredible efficiency. Many hypotheses have been put forward to explain how they can produce so much thrust with so little energy, but none has yet been proven. Now Professor Michael S. Triantafyllou has suggested that fish generate traveling vortices along their bodies which, together with the vortices shed into their wakes, create a very efficient propulsion system. Flow-visualization photographs of actual swimming fish clearly show the existence of such vortices.

This idea is an outgrowth of an ongoing project to study the wake of a thrust-generating oscillating airfoil. Professor Triantafyllou and his co-workers have shown that the manifestation of the thrust in the wake is a flow that looks like a Kármán vortex street but with reversed direction; its time average is a jet-like flow. It has a preferred frequency of maximum spatial amplification, which defines a frequency and an amplitude of large thrust development. Extensive data from published observations of swimming fish indicate that the preferred nondimensional frequency is about 0.30.

For the present, these concepts are primarily intriguing scientific ideas. But there are many areas of engineering, some with ocean applications, in which the control of vorticity (and the use of controlled vorticity) may permit the development of new systems and devices.

Drilling Dynamics. Professor J. Kim Vandiver, with support from a consortium of 14 companies, has developed procedures to monitor oilwell downhole vibration response with vibration data obtained at the surface in the drilling rig. For this purpose, Professor Vandiver and his students produced numerical models that account for the axial, torsional, and bending vibration of the drill string and the propagation of sound in the borehole. The model has now been incorporated into a commercial service for drill-string vibration monitoring, and it led to the development of a new type of drill bit, which is estimated to have saved as much as $3 million in drilling costs in a single well.

Tanker Safety. As part of the fallout of the EXXON VALDEZ incident, the National Academy of Sciences/National Research Council established a panel to evaluate alternative tanker design, with Associate Professor Henry S. Marcus as chairman. The panel's report was published during the year and, as required by the Oil Pollution Act of 1990, is being used by the Secretary of Transportation in the development of new policies on tanker design. In the meantime, the International Maritime Organization of the United Nations has established a steering committee to guide further research on a comparison of double-hull tankers and the Marine Board's recommended design. Professor Marcus is a member of that committee too.

In the meantime, the Congress mandated that tankers operating in US waters in the future must have double-skin hulls. The problem is that the mechanisms of an oil spill from a damaged ship are not understood, and it is not evident that the technology exists for designing double-skin tankers (or any other kind) to be effective in withstanding casualties like the one that befell the EXXON VALDEZ. To address this issue, Professor Tomasz Wierzbicki undertook a damage analysis of a ship grounding. The first results of that effort were reported last year. He then organized an international effort to attack all aspects of the problem; a meeting was held in Copenhagen in August with representatives of Norway and Denmark, at which the tasks were distributed among the participants. Several US organizations were then brought in to provide support, including the US Coast Guard, the US Navy, the American Bureau of Shipping, and industry.

While this organizational effort was proceeding, Professor Wierzbicki and several Course XIII-A students started the actual research program. They have already produced five papers, including analyses of the coupling of global motion and local deformation, the grounding resistance of unidirectionally stiffened double hulls, the force of a wedge cutting through a thin metal plate, and performance criteria *vs* design standards for commercial tank vessels. A major international consortium is now being created for the further study of these problems; it is expected that more than 10 agencies and companies will participate.

Hydrofoil Cavity Flows. Dr. Spyridon A. Kinnas, research engineer, Professor Justin E. Kerwin, and their students have developed and validated a computer model for the flow around a fully three-dimensional hydrofoil in the presence of a cavity. The new code is fully nonlinear, in contrast to the earlier one, which was linearized with respect to blade and cavity thickness. It allows for an accurate representation of the cavity shape at the leading edge and tip of the propeller blade, and it makes possible the study of both design and off-design conditions. The main difficulty in three dimensions is that the cavity shape and its extent are unknown *a priori* and have to be determined from the condition that the pressure is constant everywhere on the cavity surface and equal to the vapor pressure.

Experiments were made in the MIT Variable Pressure Water Tunnel to validate the computer code. These experiments included detailed measurements of the velocity field in the vicinity of the cavity as well as at other points around the foil and cavity. Wall effects were included through use of an image method. The comparison was especially good for cavities extending less than a chord length behind the trailing edge. The experimental forces, inferred from momentum integrations of the measured velocities, were also in reasonable agreement with forces predicted from the analysis.

FACULTY AND RESEARCH STAFF

Professor Emeritus Martin A. Abkowitz died January 25, 1992, after a short illness. He joined the faculty in 1948 and retired in 1988. At the request of his family, a memorial fund has been established in the Department.

Professor Randolph M. Brooks, CAPT, USN, was awarded a Navy Unit Commendation by the Secretary of the Navy "for exceptionally meritorious service in the prosecution of the TRIDENT II (D-5) Development Program."

Commander Alan J. Brown, USN, has been appointed Associate Professor of Naval Construction and Engineering, effective July 1, 1992. He received his bachelor's degree, two master's degrees, and a doctorate from MIT, the last in 1986. Commander Brown is an expert on naval ship power systems. He was recently selected for promotion to the rank of captain.

Professor A. Douglas Carmichael was elected vice-president of the Society of Naval Architects and Marine Engineers (SNAME), and he served as chairman of the SNAME *Marine Computers '91 Symposium* steering committee. Professor Carmichael continues to serve as Director of the MITES (Minority Introduction to Engineering and Science) Program of the School of Engineering and as chairman of the Institute's Faculty Instructional Resource Program (FIRP).

Associate Professor Richard C. Celotto, CDR, USN, was reassigned to a new post by the US Navy and departed from MIT in June. Professor Celotto was the first USN faculty member at MIT to be assigned simultaneously to the Naval Sea Systems Command (NAVSEA), with specific responsibility for coordinating academic inputs to the Navy's initiatives for the development of new ship concepts and encouraging the use of new technologies in ship design and construction.

Professor André Clement of the University of Paris was a visitor during the fall term, working with Professor Patrikalakis on the inspection of sculptured surfaces and large-scale metrology for shipbuilding.

Professor Leopold B. Felsen's appointment as visiting professor was extended for another three years. He is University Professor and formerly Dean of Engineering at New York Polytechnic University.

Dr. J. Robert Fricke was appointed assistant professor at the beginning of the year. He had then just finished his doctoral studies in the MIT/WHOI Joint Program with the thesis, "Acoustic Scattering from Elastic Ice: A Finite Difference Solution." Before entering the Joint Program, he had worked for eight years in the offshore industry. He has been appointed to a Doherty Ocean Utilization Career Development Chair for two years.

Professor Fricke is participating in the *Scientist-by-Mail Program* of the Boston Museum of Science. Under the program, children from around the country are provided with instructional materials to help them learn scientific principles and solve scientific problems. Professor Fricke and other program scientists receive the results, critique them, and respond appropriately. Once a year, there is a "sleep-over" at the Museum, when kids have a chance to see that science can be fun as well as challenging.

Professor Justin E. Kerwin received the Joseph H. Linnard Prize for the best paper at the SNAME Annual Meeting in November 1990. This is the third time he has won this award.

Associate Professor Judith T. Kildow returned from a one-year leave at Tufts University, where she helped organize an international environment program.

Dr. Spyridon A. Kinnas was promoted to Principal Research Engineer. Dr. Kinnas has acquired an international reputation for his research on the hydrodynamics of marine propulsors, and he has taken an active role in the supervision of student projects and theses.

Professor Koichi Masubuchi has had a prize named for him by the American Welding Society. It is awarded annually to a young person for notable achievement in welding technology. A substantial honorarium is provided by the Shinsho Corporation of Japan.

Professor Spyridon A. Mavrakos of the National Technical University of Athens is visiting in the Department for half a year. He is collaborating with Professor Michael S. Triantafyllou in research on the nonlinear dynamics of highly extensible synthetic-material lines, a problem of great importance in ocean towing.

Professor Jerome H. Milgram and his co-authors received the Alan Berman Outstanding Research Publication Award from the Naval Research Laboratory for their paper, "Hydrodynamics of Ship Wake Surfactant Films."

Professor J. Nicholas Newman was awarded an honorary Doctor of Technology degree in June by the Norwegian Technical University (NTH) in Trondheim. In its citation, NTH recognized Professor Newman's many contributions to marine hydrodynamics, including new concepts, theories, and computational methodologies, and his long-term relationships with both NTH and Norwegian industry. It was also noted that Professor Newman had spent a one-year sabbatical leave in Trondheim, when he traveled from the United States to Norway in his own sailboat. NTH awards honorary degrees only once every five years.

Professor T. Francis Ogilvie presented the commencement address at the Webb Institute of Naval Architecture in June. In March, he was named Honorary Commodore of the Quarterdeck Society, a student honorary and professional organization in the Department of Naval Architecture and Marine Engineering at The University of Michigan.

Associate Professor Nicholas M. Patrikalakis was on sabbatical leave during the spring term.

Dr. Victor I. Pavlovsky of the E. O. Paton Electric Welding Institute in Kiev, Ukraine, was a visiting engineer for much of the year. His objective was to collaborate with Professor Koichi Masubuchi on the preparation of a document integrating US and USSR knowledge on subjects related to residual stresses and distortion in welded structures. Dr. Pavlovsky's visit was supported by the American Welding Society and his home institution.

Associate Professor Henrik Schmidt is Associate Research Director of the MIT Sea Grant College Program. He has just completed his two-year appointment as Doherty Professor of Ocean Utilization.

Professor J. Kim Vandiver has completed the first year of his two-year appointment as chairman of the MIT faculty. Partly because of this assignment, he serves in an unusual number of other Institute roles, including the Faculty Policy Committee (chairman), Academic Council, Corporation Joint Advisory Committee, Provost's ROTC Working Committee, and an *ad hoc* committee (chairman) to develop charges for new Institute committees on the academic calendar and the general Institute Requirements.

Professor Tomasz Wierzbicki has been invited by the Alexander von Humboldt Foundation for another three-month visit to Germany, which he is undertaking this summer. This follows a one-year Foundation appointment as Senior US Scientist during the period of his last sabbatical leave.

Associate Professor Dick K.-P. Yue has been appointed chairman of the Institute Committee on Student Affairs.

ROBERT BRUCE WALLACE LECTURE AND PRIZE

The Tenth Robert Bruce Wallace Lecture was delivered on December 10, 1991, by ADM J. William Kime, Commandant of the US Coast Guard and an alumnus of Course XIII-A. His topic was "The Oil Pollution Act of 1990: An Opportunity for Improved Maritime Safety." The comprehensive nature of the OPA of 1990 was the focus of the lecture, including:

- the broad range of actions to protect against oil pollution being taken as a result of the act,
- the role of the Coast Guard, through its participation in the International Maritime Organization, in addressing the international problems and solutions, and
- opportunities for research and engineering solutions.

On the same occasion, the Robert Bruce Wallace Academic Prize was presented to Mr. David S. Gerson, who is now finishing a five-year program at MIT (although he is in only his fourth year here). In addition to following such an accelerated program, he has undertaken research projects in the Mechanical Engineering Department and the Materials Science and Engineering Department, he has participated in MIT athletics and other activities, and he has been a volunteer worker at Massachusetts General Hospital walk-in clinic.

STUDENT PRIZES

Besides the Robert Bruce Wallace Academic Prize, students have won the following special awards:

Mr. Mohammed Yahiaoui was co-winner of the Institute's Goodwin Medal, given annually to the "best graduate student teaching assistant" at MIT.

Ms. Maureen Stancik received a Clare Booth Luce Fellowship for the 1991-92 academic year. She was recently informed that she has won an Alfred Keil Fellowship for Wiser Uses of Science and Technology for the current year. Ms. Stancik is a student in the Technology and Policy Program as well as the Ocean Engineering Department.

As noted above (see STUDENT PROJECTS), three XIII-A students won awards from the Society of Naval Architects and Marine Engineers and the American Society of Mechanical Engineers.

EXTERNAL RELATIONSHIPS

Norwegian Technical University (NTH). The Department's three-year exchange agreement with the Marine Technology Department of NTH expired at the end of December. In view of the great success of certain aspects of the program, both sides supported a five-year renewal of the agreement, extending until December 1996. Each year, three or four Norwegian students working for their first degree (somewhere between MIT's S.B. and S.M. degrees) have completed their thesis requirements during a one-term residence at MIT. In every case, a personal relationship is first established between the student's Norwegian advisor and an MIT professor, to ensure that the topic is appropriate both to the student's program and to the MIT faculty member. It has been quite evident that NTH is sending some of its best students. A couple of them have returned to MIT for graduate study.

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, supercomputing, and basic theory. Professor Patrick H. Winston works on the problem of learning from precedents. Professor Marvin Minsky develops general theories of intelligence and knowledge representation. Professor Robert C. Berwick studies fundamental issues in natural language, including syntactic and semantic acquisition. Professor David A. McAllester works on knowledge representation and automated reasoning. Professor Lynn A. Stein works on integrated architectures for intelligence. Professor W. Eric L. Grimson, Professor Berthold K. P. Horn, Professor Tomaso A. Poggio, and Professor Shimon Ullman do research in computer vision. Professor Christopher G. Atkeson, Professor Rodney A. Brooks, Professor Tomás Lozano-Pérez, Professor Marc H. Raibert, Professor Warren P. Seering, and Dr. J. Kenneth Salisbury work on various aspects of Robotics. Professor Randall Davis and Dr. Howard E. Shrobe work on deep expert systems that use both functional and physical models. Professor Karl T. Ulrich creates decision tools for product design and manufacturing. Professor Carl E. Hewitt studies distributed problem-solving and parallel computation. Dr. Thomas Knight and Professor William J. Dally work on new computer architectures. Professor Gerald J. Sussman and Professor Harold Abelson lead work aimed, in part, at creating sophisticated problem-solving partners for scientists and engineers studying complex dynamic systems.

The Laboratory's 206 members include 22 faculty members, 19 academic staff, 33 research and support staff, and 132 graduate students active in research activities funded by the Defense Advanced Research Projects Agency, System Development Foundation, Office of Naval Research, Air Force Office of Sponsored Research, National Science Foundation, Analog Devices, Apple Computer, Bear Stearns Company, Draper Laboratory, Digital Equipment Corporation, E. I. duPont de Nemours, Exxon Research and Development Company, Fujitsu, General Dynamics, General Motors Research Laboratories, Hughes Research Laboratories, International Business Machines, ISX Corporation, Martin Marietta, Mazda Motor Corporation, MCC Corporation, McDonnell Douglas Aerospace, Mitsubishi, NASA, NATO, Sandia National Laboratory, Sharp Corporation, Siemens, Sloan Foundation, and Sperry Rand.

PRIZES, SPECIAL EVENTS, AND BOOKS

During the past year, Professors Abelson and Sussman were the co-recipients of the 1992 Bose Award given by the MIT School of Engineering for Excellence in Teaching.

Professor Abelson was chosen as one of MIT's first six MacVicar Fellows, in recognition of his sustained and significant contributions to undergraduate education.

Professor Brooks received the Hyland Lecturer Award given by Hughes Aircraft Company, and the Forsythe Lecturer Award given by Stanford University.

Professor Raibert's group's computer-generated animation film, "On The Run" won the first place award in the category of Research at the Imagina Forum for New Images held in Monte Carlo this year.

Professor Stein received the General Electric Foundation Junior Faculty Career Award, and the Class of 1957 Career Development Chair, which was established to recognize innovative and imaginative teaching by junior faculty.

Professor Ulrich received a Best Paper award at the American Society of Mechanical Engineers Winter Annual Meeting for his paper "Fundamentals of Product Modularity."

Books published this past year were *Object Recognition by Computer: The Role of Geometric Constraints* by Professor Grimson, *Handey: A Robot Task Planner* by Professor Lozano-Pérez, Joseph L. Jones, Emmanuel Mazer and Patrick O'Donnell, *The Robotics Review 2* by Oussama Khatib, John J. Craig and Professor Lozano-Pérez (editors), *L'Occhio e il Cervello: Che cosa significa "vedere."* by Professor Poggio, and *Artificial Intelligence,* (third edition) by Professor Winston.

LANGUAGE AND VISION

Natural Language Understanding and Acquisition

Professor Berwick and his colleagues have been building the next generation of natural language parsers and translators, based on modular linguistic theories. During the past year, a completely modular parser for English was extended to cover Japanese and German. This is the first complete parsing implementation of the current linguistic theory that has been developed at MIT by Chomsky, Hale, Higgenbotham, and others. Unlike extant systems elsewhere that must use a large number of completely different rules for different languages, this system uses just a handful of the same principles, parameterized in a few ways, to cover very different languages. In addition, Berwick's group explored how to learn these parameterizations automatically from the actual language input that parents provide to children, assuming the kinds of visual input and naive physical reasoning capabilities that can be reasonably assumed to be present in young children. These systems can learn what words like *roll* and *walk* mean, or that *Mary* is a thing that is also a Noun, simply by "observing" the world around them. The principle-based parsing system has been reimplemented for general distribution on Sun workstations, and extended to include a wider variety of Japanese.

Object Isolation and Identification

Work directed by Professor Ullman is exploring the problem of three-dimensional object recognition. Towards this end, Professor Ullman has developed an approach by which objects are recognized without storing three-dimensional object models. Instead, objects are recognized by using combinations of two-dimensional views. The method is based on a theory that shows that any view of a three-dimensional object can be approximated by the linear combination of a small number of its views.

Complementary work on object recognition, directed by Professor Grimson, has centered on the development of systems for recognizing objects in cluttered, noisy, unstructured environments. Such systems have been demonstrated in a variety of environments, using visual, laser, sonar, and tactile sensors. Recent efforts have focused on establishing a formal theory on which to judge the efficacy and robustness of recognition methods, on exploring alternative matching schemes for recognizing objects, on grouping methods for preprocessing the input data into salient sets of features, on the role of visual attention in recognition, and on the use of current recognition systems in practical applications.

Motion Vision and Low-Level Integration

Professor Horn and his students work on problems in motion vision. Currently, the extension of existing methods in the time direction is being explored. While one can get good motion information from just two image frames, distances to objects are determined only rather coarsely. Meth-

ods 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.

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.

Finally, work on a new special-purpose early-vision analog VLSI chip will be completed soon. This chip determines the "focus of expansion"—that point in the image towards which the camera appears to be moving. The chip is expected to operate at 1000 frames per second. While it has only a 32 x 32 array of sensors and processing elements, it is expected to be able to recover the focus of expansion with sub-pixel resolution.

Machine Learning and Networks

Professor Poggio regards learning as a problem of approximating a multivariate function from sparse examples. Professor Poggio's group has developed a technique, based on *regularization theory*, that has roots in the classical theory of function approximation and that has illuminating relations with other fields. The computations center on what Poggio calls HyperBf functions, a generalization of radial basis functions. These functions dictate computations that are equivalent to those performed by of a certain class of multilayer networks.

During the past two years the theory has been substantially developed with several theoretically significant results. Recently, for example, an interesting relation between HyperBf networks and multilayer perceptrons has been demonstrated. Also, new theorems characterizing the number of examples needed for learning as a function of dimensionality and smoothness of the function space have been obtained. The technique has been compared successfully in numerical experiments against other statistical and neural network techniques.

Several applications have been demonstrated. The main ones are in 3D object recognition, in synthesizing vision algorithms for specific tasks, such as hyperacuity tasks, and in a new approach to computer graphics.

The theory was originally developed without any direct biological motivation. It appears, nevertheless, that HyperBF networks may have a very simple and appealing interpretation in terms of neurons with Gaussian-like receptive fields and modifiable synapses. In addition, the model of 3D object recognition has been supported by psychophysical data about human vision and is consistent with neurophysiological data on cortical neurons involved in face recognition.

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 a number of fronts: integrating complex systems into kilogram scale robots, developing simple visual reflexes for mobile robots, understanding how multiple robots can work together and producing extremely tiny robots.

During the past year, Maja Mataric demonstrated how robust, cooperative group behavior can emerge from the behavior of individual robots which have no explicit group behaviors programmed in. Up to 12 mobile robots have been operated simultaneously to demonstrate fundamental group behaviors such as dispersion, flocking, homing and following. When the robots operate, there is no central control, there is no explicit communication between the robots, and there is no explicit leader. Instead, each robot relies on its to sense the presence of another robot and know that it is a robot of the same type as itself.

Planning For Collision-Free, Compliant, and Grasping Motions

Professor Lozano-Pérez and his associates have completed development and testing of the Handey task-level robot system. The completed system is described in a recent monograph from MIT Press. 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.

Legged Locomotion

Professor Raibert and members of the Leg Laboratory have studied legged locomotion in a variety of legged systems, including laboratory robots and computer simulations of animal-like systems. During the past year, they have controlled the behavior of a three-dimensional biped robot with telescoping legs, computer and physical models of a kangaroo, and a computer simulation of an ostrich.

Robot and Human Arms and Hands

The Salisbury articulated hand mounted on a PUMA arm serves as a test bed for a wide range of grasping and path planning experiments. Dr. Salisbury's group is currently using this hand/arm system to develop sensor reactive grasping strategies aimed at locally robust object acquisition in both terrestrial and zero-gravity environments. A variety of sensors including a palm sensor, 6-axes fingertip force sensors and piezoelectric intermediate link sensors are used to provide incrementally increasing knowledge of target objects.

A high performance cable driven arm (WAM), developed by Dr. Salisbury's group, has been the focus of a number of novel manipulation and control investigations. Professor Slotine's group, from MIT's Non-Linear Systems Laboratory, has developed and implemented a series of adaptive non-linear control systems for the WAM arm which permit significantly improved performance in free and constrained motions. In addition, they have developed an approach for robust and predictably stable force reflecting teleoperation in the presence of time-vision. The arm has successfully caught objects in cooperation with a stereo vision system. A new integrated hand/wrist system is being developed for the arm which will be used in robotic and telerobotic applications ranging from real-time catching of rotating objects to unstructured grasping.

Motor Learning

Professor Atkeson's group focuses on learning, and uses robotics as a domain to explore learning algorithms and approaches. One major research area is memory-based learning, which defers data analysis until data is needed to answer a specific question. The group has used memory-based learning to train robots to perform challenging dynamic tasks such as juggling.

The group is now developing cross validation techniques to fine tune memory-based learning algorithms to particular problems, so that one generic algorithm can handle a wide range of problems without human intervention. To demonstrate generality, the group is applying memory-based learning to the control of complex mobile robots (such as autonomous helicopters) and complex processes (such as an internal combustion engine).

A new area of interest is using learning to refine and even discover strategies to perform tasks. The focus is on the design of dynamic processes. Several machines have been built, including a world-record-holding bounce juggling machine.

REASONING TOOLS FOR ENGINEERS AND SCIENTISTS

Mixed Symbolic and Numerical Computation

The research of the MIT Project for Mathematics and Computation (Project MaC), under the direction of Professors Abelson and Sussman, is working to demonstrate breakthrough applications that exploit new computer representations and reasoning mechanisms that they have developed. These mechanisms enable intelligent systems to autonomously design, monitor, and understand complex physical systems, through appropriate mixtures of numerical computing, symbolic computing, and knowledge-based methods. They call this mixed approach *intelligent simulation.*

During the past year, one member of the group, Feng Zhao, has constructed and demonstrated a suite of programs that automatically analyzes and designs controllers for high-performance, global control of nonlinear systems. These programs combine powerful techniques from numerical and symbolic computation with novel representation and reasoning mechanisms from artificial intelligence.

To demonstrate the power of this approach, Zhao used these programs to synthesize, automatically, a high-performance controller for a magnetic-levitation system (the German Transrapid system). In simulations, the new control system has stabilized magnetic-levitation vehicles with displacements of up to 20 times those allowed by a previous controller design that was developed for the same system using linear-feedback techniques.

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.

New work is focused on understanding how things work in a variety of domains, including simple mechanical devices like four-bar linkages, and mechanistic explanations of biological phenomena. Examples of understanding include the ability to produce descriptions of device behavior from a description of their structure, the ability to predict behavior under unusual circumstances, and the ability to redesign to fit those new circumstances.

This work is based in part on the belief that the next major innovation in computer-aided design will be the construction of tools that understand (and can be told) how devices work and that can use this knowledge to support intelligent design modification. In order to be successful, such systems must already know a great deal of the basics of its design domain. I should know, for example, what a mechanical engineer means by terms such as "Scotch Yoke," "Four Bar linkage," and "Trip Mechanism."

Engineering Problem Solving and Design

Professor Ulrich and his students research computational tools for product design and manufacturing. The philosophy underlying their research is that close involvement with industrial practitioners is essential to effective problem definition. Accordingly, the group has research partnerships with The Boeing Company, United Technologies Corporation, and The Stanley Works.

One project aims at creating simple, powerful, and intuitive tools for solving parametric design problems. The project is motivated by the observation that approximately 75% of all mechanical engineers use commercially available business spreadsheets to do their parametric engineering problem solving, yet these tools only support a limited unidirectional problem solving metaphor. This work has led to the development of an "engineers' spreadsheet," which is being used to design a novel power tool in collaboration with Stanley.

Another project focuses on the problem of providing real time evaluation of the producibility of mechanical parts, based only on preliminary part geometry. The approach is to integrate knowledge of the physics underlying the intended production processes with computational geometry techniques. One intermediate research result is a technique and tool for identifying potential production problems for aluminum extrusions.

During the past year, Professor Seering's group has made advances in understanding the dynamic response characteristics of robot arms. The focus of the group's work has been on system identification and on exploring control strategies for improving robot performance under force control. Efforts are also ongoing on minimizing undesirable vibrations in dynamic systems. In collaboration with NASA the group has been working to improve the response of the space shuttle robot arm.

Professor Seering's students have also been looking for ways to use computers to help mechanical designers. As part of this activity, they have been working to capture design documentation so that it can be retrieved efficiently and at the desired level of detail by a designer. Some of this work builds on work on decision rationale representation initiated in Professor Winston's group.

HARDWARE AND SOFTWARE ARCHITECTURES

Symbolic Parallel Architectures

The Symbolic Parallel Architecture group, under the direction of Dr. 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. 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 SIMD computer for early vision applications has also begun. The architecture maximizes the number of bits transformed each cycle by allocating a very simple processing element to each bit of a data item. Simulation of low-level arithmetic primitives has been completed, and preliminary VLSI layout issues are now being addressed. A system composed of 144 chips is expected to deliver between approximately 100 billion 16-bit arithmetic operations per second.

Message-Passing Semantics

The Message-Passing Semantics group, under the guidance of Professor Hewitt, has been developing the foundations for Open Systems that perform robustly in changing environments. The group's research focuses on theoretical, architectural, and linguistic aspects of organizational systems composed of humans and telecomputer systems. During the past year research was focused on the beginnings of mobile telecomputer systems as an important domain of application.

BASIC THEORY

Society of Mind

Professor Minsky has continued to develop the theory of human thinking and learning called the "Society of Mind." This theory explores how phenomena of mind emerge from the interaction of many disparate agencies, each mindless by itself. For example, one aspect of the theory explains the combination of knowledge representations in different realms of thought as the basis for analogy; another aspect is a "re-duplication" account of natural language, in which grammatical forms are seen as emerging directly from expressive requirements rather than from conventions that communications are forced to fit.

Professor Minsky has continued his interest in the limits and potentials of "connectionist learning systems" and their role in distributed cognitive accounts like the Society of Mind. He is actively considering how such systems may be combined and interconnected in a way that avoids the serious scaling problems of unstructured connectionist systems.

Automated Formal Reasoning

Professor McAllester has been building and testing automated reasoning systems. These reasoning systems incorporate a variety of new algorithmic techniques that allow effective automated reasoning about topics that are beyond the scope of any previous reasoning system. For example, the new reasoning systems have been able to verify proofs, starting with only the axioms of Zermelo-Fraenkel set theory, of the Stone representation theorem in lattice theory. This theorem involves an ultrafilter construction and is similar in complexity to the Tychonoff theorem that a product of compact topological spaces is compact. The novel algorithmic techniques include the integration of congruence closure into general theorem proving, monotone closure for reasoning about semantic types, focused forward chaining, and the incorporation of universal generalization into constraint propagation. In addition to evaluating automated reasoning systems in terms of their ability to verify abstract mathematical theorems, Professor McAllester is studying the application of automated reasoning systems in software verification. In particular, Professor McAllester has begun to concentrate on the special case of verifying computer programs to be "uncrashable."

Commonsense Reasoning

Professor Stein's group works on integrated architectures for intelligence. The goal is to understand how an agent can exhibit a capacity for abstract reasoning, even though the agent is limited by the sensory and computational realities that govern the operation of robots in physical, rather than simulated worlds. In one project, a society of robots performs a task for which communication and coordination is a prerequisite. In order to communicate, the society as a whole must agree on a conceptualization of the world and a mapping from communication signals onto this conceptualization. Thus, symbolic intent emerges from interaction with the world and with the agent's society. Another project addresses the issue of abstracting away from interactive tasks by allowing the agent to learn by imagining. Reusing its existing hardware and software, a navigating agent

learns to interpret directions by imagining that it is acting in the world. A second mode of cognitive ability is thus built on top of the first.

Learning from Analogous Precedents

Professor Winston's group has concentrated recently on developing representations that enable learning and reasoning by analogy. During the past year, considerable progress was made on the particular problem of representing change qualitatively, such that a remembered sequence of changes can be used as a precedent for understanding how some subsequent situation is evolving. A key insight is that there is much to be gained by viewing the world from a transition-centered perspective, rather than a state-centered perspective. Using "transition space," the recently implemented Pathfinder program combines background knowledge with descriptions drawn from the Encyclopedia Americana to answer questions about, for example, how rockets work.

PATRICK H. WINSTON

DIRECTOR

Biotechnology Process Engineering Center

The Biotechnology Process Engineering Center (BPEC), an interdepartmental center at the Massachusetts Institute of Technology, is a pioneering program in education and research for the biotechnology industry. BPEC, funded by the National Science Foundation (NSF) under the Engineering Research Center Initiative, was established in May, 1985. The NSF has approved further funding for BPEC through January, 1996.

As an interdepartmental center, the BPEC reports to the Dean of Engineering, Professor Joel Moses. The Director of the center is Daniel I.C. Wang, Professor of Chemical Engineering. Three associate directors assist in the overall operations of the center: Charles L. Cooney, Professor of Chemical Engineering and Associate Director for Industry; Gregory N. Stephanopoulos, Professor of Chemical Engineering and Associate Director for Research; and Anthony J. Sinskey, Professor of Biology and Associate Director for Education.

The BPEC takes an innovative, cross-disciplinary approach to biotechnology, integrating life sciences and bioprocess engineering with the goal of producing advanced manufacturing technology. The main goal of the center is to create a new breed of professionals to enhance this nation's international competitiveness in biotechnology manufacturing. To achieve this goal, the center focuses its efforts through education, research, and industrial involvement. Cross-disciplinary educational and research collaborations are especially important components within the center's activities.

A team of 14 faculty members participated in the center's activities during Fiscal 1992. BPEC faculty are drawn from two schools and four departments at MIT. Within the School of Engineering, we have faculty from the Department of Chemical Engineering and the Department of Electrical Engineering and Computer Science; within the School of Science, we have faculty from the Departments of Biology, Chemistry, and the Whitehead Institute. The BPEC also has one faculty member from the Department of Chemistry at Harvard University. Undergraduate and graduate students, post-doctoral fellows, visiting scientists, and industrial associates are integral participants in the center's activities. A summary of the BPEC personnel during Fiscal 1992 is tabulated below.

o MIT Undergraduate Research Opportunity Program	= 55	(4 Departments)
o NSF Research Education for Undergraduates (REU, Non-MIT Undergraduates)	= 10	(10 Univers.)
o Graduate Students	= 78	(8 Departments)
o Technical Assistants	= 5	
o Post-Doctoral Associates	= 8	
o Visiting Scientists & Engineers	= 14	
o Visiting Faculty	= 1	
o Other Administrative Personnel	= 16	
TOTAL	187	

The major financial support for BPEC personnel is provided by the NSF. Additional support for graduate educational activities for the MIT students is provided by the National Institutes of Health (NIH-

NIGMS). In addition, unrestricted funds have been secured from outside sources. Industrial donations were received in the form of contracts, fellowships, equipment, and software.

EDUCATIONAL ACTIVITIES

The center's faculty members again taught an interdisciplinary undergraduate course, 7.52J/10.56J, Biotechnology of Mammalian Cells. Funds for the teaching assistants for this course were provided by the center. All of the BPEC faculty taught existing courses in their respective departments which dealt with biotechnology.

BPEC continued to hold two very active undergraduate programs during Fiscal 1992. The programs are the Undergraduate Research Opportunities Program (UROP) and the Research Experience for Undergraduates (REU). Fifty-five UROP students from all four departments participated in the center's research program this past year, including 25 minority students. In addition, an undergraduate outreach program funded separately by the NSF under the REU program supported 10 non-MIT students. These non-MIT REUs were from 10 different universities and colleges throughout the United States. We continued our seminar program entitled, "UROP and REU Seminar," in which the undergraduates presented their research experiences to the center's personnel on a weekly basis. To summarize, with both the UROP and REU programs in mind, the following BPEC undergraduate achievements were accomplished during Fiscal 1992. The students were provided with basic research tools as part of overall educational program; BPEC instilled cross-disciplinary and team research in each student; the student gained communication skills through a special seminar program; and BPEC established an outreach program (REU) to provide research experience for other universities.

At the graduate level, we have continued to bring interdisciplinary concepts into the course teachings. We successfully completed our third year on the Interdepartmental Biotechnology Program (IBP) which was officially inaugurated in 1989. Funding for this program is provided by the NIH-NIGMS, a training grant designed to support 14 pre-doctoral candidates for the first year and second year and 21 candidates for the third through the fifth year. This program involves 33 faculty members from MIT representing the Departments of Biology, Chemistry and Chemical Engineering. The center's Director, Professor Wang, is also the director of this program. Professors Jonathan A. King and Anthony J. Sinskey are Co-Chairman.

Industrial educational activities were achieved through the Special Summer Course Program at MIT. In Fiscal 1992, six special summer courses under the auspices of the BPEC were presented. They were, "Biotechnology Principles and Processes"; "Fermentation Technology"; "Downstream Processing"; "Controlled Release Technology"; "Modeling, Simulation and Optimization of Chemical Processes"; and "High School Science Teacher Program". Four mini-courses were taught by BPEC Faculty at industrial sites. They were: "Fermentation Technology" at Merck, Sharp and Dohme; "Biochemical Engineering" at Pfizer, Inc.; "New Separation Processes" at Phillips Petroleum; and "Biotechnology" at Dupont. In addition, courses were presented by BPEC faculty at the University of Minnesota, the AIChE meeting, Steven Institute, Cold Spring Harbor and the University of Singapore.

As part of BPEC's effort to foster technology transfer, it has established an Industrial Consortium Office. Its responsibilities include coordinating company visits; disseminating research abstracts, published papers, and student theses; organizing workshops and symposia; and maintaining a database of BPEC research projects. This office works closely with the BPEC faculty, BPEC students, the MIT Industrial Liaison Program, and the MIT Technology Licensing Office in order to serve company needs.

Topic oriented workshops play an important role in BPEC's technology transfer program. By bringing company representatives together to discuss a common topic, these workshops provide a forum for education and company-company interactions. The BPEC has held workshops on the following topics: animal cell science and technology, downstream processing, process control and scale-up, advances in membrane technology for bioprocesses, bioinstrumentation, industry regulation, protein expression systems, bioremediation technology, biosensors, and proteins on pharmaceuticals. Typically, these workshops draw from 30 to 50 attendees from 20 to 30 companies. The center has also attempted to hold these meetings at locations other than MIT, so as not to create a geographical bias towards certain companies.

Below is a summary on some of the other achievements of the BPEC during 1991-1992:

o Publications	= 251
o Presentations at Conferences and Symposia	= 161
o Industrial Seminars	= 61
o University Seminars	= 72
o Theses	= 23
o Company Visitors to BPEC	= 77

NEW APPOINTMENTS AND INITIATIVES

As an effort to strengthen and increase the research capabilities of the BPEC, a new faculty outreach program was initiated. This effort is directed towards the area of bio-analytical chemistry to characterize the quality of proteins from the recombinant DNA technology. During the summer of 1992, two visiting professors, both world renown in the field of bio-analytical and bioseparation of complex proteins, have been invited to the BPEC. Professor Fred Regnier from the Department of Chemistry at Purdue University will bring his expertise to the BPEC in the area of analytical and preparative scale in bioseparation. Professor Cheng S. Lee from the Department of Chemical and Biochemical Engineering at the University of Maryland, Baltimore County, will aid the BPEC in the area of capillary electrophoresis.

Daniel I. C. Wang
DIRECTOR

CURRENT RESEARCH

The vision and goal of this ERC is to develop advanced concepts for the manufacturing of complex proteins and to train a new breed of professionals with the cross-disciplinary skills needed to support the biotechnological industry. Many therapeutic proteins cannot be made in prokaryotic organisms and thus new concepts are needed to synthesize and recover these materials from animal cell cultures.

The research thrusts of the BPEC are designed to solve near and long term problems, and as such, have impacted on the United States biotechnological manufacturing capabilities and international competitiveness. Training people, performing research, and working with industry, are central BPEC goals and are the mechanism through which we will deliver the benefits of our work.

Two research thrust areas are being pursued at the center. The first area is focused on the "Engineering and Scientific Principles in Therapeutic Protein Production". The BPEC mission in Thrust I takes a systems approach to develop an understanding of the interrelationships between performance of a bioreactor and its design as influenced by its physical and biological environment. Important relationships to be established include the number of living mammalian cells in a given bioreactor and their functions and the amount and quality of product. This knowledge will allow one to design better bioreactors and systems; provide proper surfaces for cell growth and product formation; formulate optimal media; and finally optimally operate and control the bioreactor for the manufacture of complex therapeutic proteins.

The second thrust area is focused on "Integration of Process Engineering and Science of Therapeutic Protein Purification". The goal in manufacturing therapeutic proteins is production of very pure, homogeneous and fully functional protein preparations. Some of the engineering problems in achieving this goal originate in upstream manufacturing, e.g. heterogeneity in post-translational processing, insoluble aggregate formation, impurity and contaminant introduction. Many other problems develop in the course of the downstream process itself, e.g. specific and non-specific surface interaction, solution and solid phase stability, variable refolding, and aggregation during refolding. The mission of the center is to establish the relationship between the bioprocess environment on one hand, and process yield and product quality obtained from protein purification on the other. In order to accomplish this mission, center research must develop the science base underlying the observed phenomena and also facilitate the application of the knowledge to the improvement of product purification operations.

INDUSTRIAL COLLABORATIONS AND TECHNOLOGY TRANSFER

Industrial collaborations and technology transfer are important goals of the center. In 1986, our Industrial Consortium Program was established with a membership of 38 companies. The Consortium had a membership of 62 companies in Fiscal 1992, representing the entire spectrum of the biotechnology industrial sectors. During this period a total of thirty-two collaborative industrial projects were in place. Lastly, during Fiscal 1992 there were 13 industrial scientists and engineers in residence at the center.

Center for Advanced Engineering Study

The Center for Advanced Engineering Study (CAES) was founded in 1963 for the purpose of developing educational programs that provide opportunities for practicing engineers, scientists, and managers in industry, government, and educational institutions to attain and maintain the competence needed to exert technological leadership. Alfred P. Sloan, Jr. provided both the impetus and the funds to get the center started. Building 9 has been the home of CAES since its completion in 1968.

To achieve its objectives, CAES has traditionally offered two types of educational programs at the workplace and on-campus for the practicing professional. For those at the workplace, the center provides studio-based and classroom-based video courses which are produced at the center in collaboration with MIT faculty and research staff. Richard J. Noyes is the director of the video-based programs. The on-campus Advanced Study Program, directed by Dr. Paul E. Brown, provides the participants with individualized study and/or research that is tailored to their backgrounds and designed to meet their needs and the objectives of their employers.

During the 1991-92 academic year, 67 professionals participated in the Advanced Study Program, 29 from the United States and 38 from 9 other countries. These Fellows attended regular graduate and undergraduate subjects that suited their needs. In addition, many of them performed individualized studies guided by faculty members and several participated in ongoing research programs. Also, the center sponsored several subjects that are of particular interest to the Fellows, such as Project Management and Management of Technological Change. These subjects are listed in the MIT course catalog and are, of course, open to MIT students. CAES, in addition, offered informal evening classes in Artificial Intelligence and Expert Systems.

The Fellows in the Advanced Study Program are provided with study offices, computer facilities, and a videotape library with viewing facilities. The computer facilities include IBM and Macintosh computers, and DEC VAX workstations connected to the Project Athena Network, which integrates computers into the educational environment in all fields of study. We also offer a weekly luncheon seminar at which the Fellows give brief presentations of their work. Center staff and faculty also make presentations at these seminars.

CAES video-based educational programs focus primarily on recent developments in MIT research. These video courses are used at the workplace by a broad spectrum of businesses, government agencies, and educational and training institutions to instruct their engineers, scientists, and managers. Recent video releases include: *Managing Innovation Through Lead Users* by Prof. Eric von Hippel; *Fundamentals of Image Processing* by Prof. William Schreiber; *Video Demonstrations in Lasers and Optics* by Prof. Shaoul Ezekiel; *Taguchi Quality Engineering System for Robust Design* by Prof. Don Clausing; *2-D Signal Processing and Image Processing* by Prof. Jae Lim; *Understanding Lasers and Their Applications* by Prof. Shaoul Ezekiel. In addition, eight programs that originated as satellite broadcasts this year have been edited for marketing as video courses. They include: *Enhanced Quality Function Deployment* by Prof. Don Clausing; *Building Your House of Quality* by Prof. Don Clausing; *Principles and Applications of Image Processing* by Prof. William Schreiber; *LEX and YACC: Designing and Developing Tools for the UNIX Environment* by Dr. Steven Lally; *Automatic Speech Recognition and Understanding* by Dr. Victor Zue; *New Parallel Architectures and Languages* by Prof. Arvind; and *Microlithography Strategy for Future ULSI* by Prof. Henry Smith.

We are currently developing *Total Quality Management*, a video course with excerpts by various authors of existing CAES management video courses. We are also planning to produce a series of interactive multimedia modules in collaboration with the Engineering Design Instructional Computer System Program. The content of the modules will cover the Design curriculum of the Department of Mechanical Engineering. In addition, *Video Demonstrations in Lasers and Optics* by Prof. Shaoul Ezekiel will be converted to an interactive laser disc format. All video courses are professionally videotaped by center staff in the CAES television studio in Building 9, in large lecture halls, or in designated classrooms.

In order to enhance the Institute's well established role in continuing education, CAES is constantly searching for new initiatives in educational programming to strengthen MIT's coupling to industry, both local and out-of-state. One such initiative is "A Day with an MIT Professor," a non-credit, on-campus program held on Saturdays. Participants spend a day with a faculty member in an informal atmosphere which gives them an opportunity to examine a specific topic in depth through direct interaction with the faculty member as well as with the other participants. These programs are tutorial in nature and emphasize fundamentals as well as recent developments.

In addition, the center will continue broadcasting via the NTU network, by satellite, engineering and timely management subjects. These broadcasts are organized around single themes that focus on practical applications and are usually presented by one speaker over several hours in a single day. The transmissions are carried on KU-band frequencies to businesses, government agencies, and universities. Eight satellite broadcasts were transmitted during the winter and spring of 1992. Those programs are listed in the recent release video course descriptions above. CAES plans to broadcast at least another seven satellite courses in the winter and spring of 1993. These include: *Understanding Lasers and Fiber Optics* by Prof. Shaoul Ezekiel; *Designing Products that Sound Good* by Prof Richard Lyon; *Fault Tolerant Control Systems* by Prof. Wallace Vander Velde; *Management of Technological Change* by Prof. Ernst Frankel; *Key Topics in Finite Element Analysis* by Prof. Klaus-Jürgen Bathe; *Object-Oriented Systems* by Prof. Duvvuru Sriram.

To further extend the outreach of MIT's continuing education efforts, CAES, in cooperation with the Industrial Liaison Program, is planning to develop and test a dedicated MIT satellite channel during the spring of 1993. The test schedule for the channel will focus on ILP Symposia and selected seminars. We currently project 100 hours of broadcast programming during the test schedule. The objective of this new initiative is to further strengthen the link between MIT and industry, government, and other universities via live, satellite broadcasts of a rich variety of non-credit programs.

CAES is also administering a Systems Engineering and Technology Management Program sponsored by the Department of Aeronautics and Astronautics. Other departments participating include the Sloan School of Management and the MIT Leaders for Manufacturing Program. The four-week program now planned for January 1993, will emphasize case studies and classroom course work in the areas of systems engineering-analysis, integration and verification; advanced technologies and applications; risk analysis, reliability, and quality management; fundamentals of cost estimation, budgeting, and control; aerospace economics in a world economy; and advanced engineering practices.

The summer of 1991 was the fifth year of CAES participation in a unique initiative to provide continuing education for engineering faculty in US colleges. Special two-week intensive courses were offered by universities and industrial organizations with the major support coming from the National Science Foundation. Over 690 faculty have attended such programs so far. CAES plays a key role in the organization, coordination, and administration of this program under the aegis of the American Society for Engineering Education (ASEE).

The CAES Video Production Services group continues to provide a full range of affordable services for the Institute. Any Institute video need can be taped efficiently and at a reasonable cost at any campus location and at the CAES television studio. Facilities and services include, among others, a full-production television studio, a television classroom, videotaping on location, on-line and off-line editing, plus videotape duplication. The recent completion of the new on-line edit suite with full Beta SP recording and editing equipment keeps CAES at the cutting edge of broadcast-quality television.

SHAOUL EZEKIEL

Center for Technology, Policy, and Industrial Development

INTRODUCTION

A most important development during the previous year has been the formation of the Technology, Management and Policy Program (TMP), a new cooperative framework in which the Center for Technology, Policy and Industrial Development (CTPID) will participate. TMP brings together CTPID, the Technology and Policy Program (TPP) and several other centers and laboratories in a cooperative arrangement for joint research and educational initiatives. The program provides a cooperative framework for faculty to develop critical size research and educational activities by building on the collective resources of the participating units. TMP is described elsewhere in this report.

During the past year, several programs, such as the International Motor Vehicle Program and the Hazardous Substances Management Program, have evolved into new phases. A new communications policy program has been initiated and the Materials Systems Laboratory has become an integral part of the center's operations. Also, a new project focusing on the industrial ecology of chlorine is an important component of our environmental policy activities and complements the research of the Technology, Business and Environment Program.

RESEARCH

Industry Studies

International Motor Vehicle Program (Auto 21): IMVP has been a major research program at the center over the past seven years. This program, coordinated by MIT, has involved researchers from throughout the world. The program focuses on understanding the role of the automobile as a transportation mode and as a source of social change, what constitutes "best practice" in automobile production, and the dynamics of international competition that is reshaping the automobile industry.

The new phase of the program (IMVP - Auto 21), initially funded by a two-million-dollar grant in 1990 from the Alfred P. Sloan Foundation, builds upon and expands the earlier five-year effort at MIT conducted between 1986 and 1990. The earlier phase had consisted of comparative international research focusing on best practice techniques in all aspects of motor vehicle production, including research, product development, manufacturing and distribution. A principal finding was a new systematic framework for the entire production process, characterized as "lean production." The results have been summarized in the book, The Machine that Changed the World (James P. Womack, Daniel Jones and Daniel Roos; Rawson Associates, a division of Macmillan Publishing Company, 1990).

The new phase of the program, involving the active participation, cooperation and support of companies and government organizations concerned with the motor vehicle industry, has a broader agenda: it focuses on competitiveness issues affecting the industry and the ways in which the motor vehicle industry interacts with its environment. Four major objectives guide the new program: expanding our understanding of best practice techniques, broadening measures of industrial performance, integrating environmental considerations into corporate strategy and performance, and transitioning from mass to lean production.

In light of these objectives, the new program has focused on four major areas: product development, manufacturing practice, supplier performance and relations, and environmental issues and the transportation system. During the past year, research activities have been broadened in all four areas. The program, being undertaken by the center in conjunction with the School of Engineering and the MIT Sloan School of Management, is supervised by Professor Daniel Roos, Director of CTPID.

Telecommunications Policy: Developments in fiber optics change the context and delivery systems for many discrete services that can now be combined. The issues of what services to provide, through which industries to provide them, and how to provide them represent fundamental technological and policy issues. The center has just begun a new program funded by the Defense Advanced Research Projects

Agency (DARPA) and private industry to explore these issues. This program is part of a broader initiative launched this year by the center, known as the Program on Digital Open High Resolution Systems (DOHRS). DOHRS is focusing on critical technical and policy issues for the design and implementation of open interfaces for high performance computing and communications systems, in particular the emerging National Research and Education Network (NREN). In view of the fact that the federal government is planning to allocate about one billion dollars to support the research for and use of the NREN over the 1992-1997 time period, this area should provide an important new research opportunity both for the center and for other MIT centers and laboratories.

Program researchers organize periodic meetings at the Library of Congress with congressional staff, executive branch, industry and academia, on information and communication technology and policy options. They also assist, organize and participate in industry-government-academic workshops as well as in academic conferences on critical issues involving future communications systems. Further, they contribute comments to the Federal Communications Commission's regulatory proceedings on related issues and are publishing scholarly work in the field. A book supported by the Markle Foundation, and coauthored by W. Russell Neuman, Lee McKnight, and Richard Solomon, will be published by the MIT Press in December 1992. The book is tentatively entitled, "The Gordian Knot: Political Gridlock and the Communications Revolution."

Materials Policy: Materials policy issues are currently being addressed by the Materials Systems Laboratory (MSL), now a part of the center. Through Technical Cost Modeling, a cost analysis methodology that has been developed and continuously refined by the MSL over the past ten years, problems in material selection, product design, and process development in fields ranging throughout the materials industry can be addressed. The future of material usage in the automobile has been one of topics most intensely researched by MSL. Research findings from this effort are being shared with the International Motor Vehicle Program.

The MSL has begun analyzing issues related to industrial ecology. As part of the research on the automobile industry, the recyclability of various alternative materials is being evaluated, considering technical, cost, performance and other criteria. These research activities should serve as a basis for other studies of the impacts on the environment of large-scale industrial systems.

In addition, MSL researchers are exploring how industrial practices are being influenced by cost measurement practices. A strong agreement exists among industrial managers that existing accounting methodology does not accurately describe many of the costs and benefits that arise from new materials technology. MSL is thus exploring the further refinement of the Technical Cost Modeling methodology to improve managerial decision making with respect to the selection and use of new materials technology.

Environmental Studies

Technology, Business and Environment Program: During the past year, under the direction of Drs. John Ehrenfeld and James Maxwell, this program, formerly the policy component of the Hazardous Substances Management Program, has expanded into a full-blown research activity in the center examining the fundamental relationship between technology and the environment, and, in particular, the role of businesses as principal agents of technological change.

This evolving research activity, named the Technology, Business, and Environment Program, has been examining environmental management practices through a series of case studies on firms in the chemical, automobile, electronics, and consumer products industries. Firms throughout the world are facing mounting, and unprecedented, regulatory and market pressure to improve their environmental performance. One focus of research is on understanding how firms are designing and implementing strategies in response to these environmental pressures, for example by integrating environmental management into their mainline management practices and by introducing environmental concerns into product and process design.

This research also explores the relationships among such variables as corporate environmental performance, quality, and productivity. It is usually thought that there exists a tradeoff between

environmental and economic performance. A maintained hypothesis in this research is that there may be certain cases where environmental improvements can be made without sacrificing economic development. In such cases, environmental management would resemble total quality management at the firm level. These issues are being examined in the context of automobile manufacturing.

Over the past year, the MIT Workshop on Business and the Environment held a series of monthly seminars, attended by business and industry leaders, faculty from MIT and neighboring schools, representatives of nongovernmental organizations, government officials and students. These seminars have helped shape the research and academic agenda focusing on the environment and have served as a sounding board for the ideas that are emerging. Corporate attendees have already started implementing new practices learned informally at these seminars.

Chlorine Industrial Ecology Program: The major objective of this new interdisciplinary research effort is to study the relevance, feasibility and implications of alternative longer-term technical, management and policy options internationally concerning the production, use and disposal of chlorine-related products, including current initiatives to phase-out or eliminate some or all of them. Under the direction of Drs. Kirkor Bozdogan and John Ehrenfeld, the exploratory first-phase of the project has started to develop a chlorine industrial ecology database and has initiated a number of preliminary analyses focusing on major product or use areas, such as chlorofluorocarbons (CFCs) and industrial solvents, pulp and paper industry, polyvinyl chloride (PVC), and chlorinated pesticides.

Superfund Project: A research team at the center has completed a study of new and improved priority-setting methods for Superfund. The study was organized to answer the following question: Is it possible to set priorities early in the site assessment process in order to sort National Priority List sites into those which should be priorities for assessment and remediation and those which should be dealt with after other priorities have been met?

Several priority-setting procedures have been explored and defined. These procedures are characterized in terms of their technical risks, potential consequences, administrative framework, and other factors, such as their timing as well as analytical and data requirements. These priority-setting procedures have been further examined in terms of their rationale, expected benefits, and barriers to their successful implementation. Overall benefits of the respective procedures over time have been analyzed through the use of a systems dynamics model. It is anticipated that, in the long run, overall risks will be reduced through the careful selection of sites for current attention. The recommended schemes should introduce programmatic, integrated, decisions into a system where every site is acted upon independently and without regard to the overall set of priorities and available resources. Many of the suggested recommendations can be implemented without legislative change.

Law and Technology: The interface between law and science and technology is researched, by Professor Nicholas Ashford and others at the center, stressing public health, workplace safety and the environment, with major emphasis on the recognition and regulation of chemical hazards. Another area of research includes labor-management relations, concentrating on such topics as discriminatory practices in the workplace and the right to refuse hazardous work. A third area studied is law and technological change, with primary attention to issues covering the impact of regulations on the chemical industry, using regulation to stimulate technological change, the impact of liability on the chemical industry, and transferring technology to developing countries.

The research in law and technology has led to the development of four courses by utilizing interdisciplinary approaches to the study of technology and society. These courses not only introduce students to legal reasoning but also provide a unique framework for integrating legal, economic and public policy analysis, with major emphasis on environmental issues.

EDUCATION

The Technology and Policy Program, the recipient of two recent prizes for the most significant contribution to MIT education, has established the largest, top-rated, graduate program worldwide in the area of technology and policy. Currently the educational offerings include a Master of Science degree

(about 80 students), as well as the Ph.D. degree administered on an ad hoc basis (about 15 students), in Technology and Policy, in addition to service courses and short courses for mid-career professionals.

The Program has approximately 300 graduates. During the past year, as in previous years, graduating students have been successfully placed in both industry and government, in the United States as well as abroad. Similarly, the Program has successfully placed graduating students in faculty positions at such universities as Harvard, Brown, Columbia, Lehigh, Princeton, Johns Hopkins, University of California at Berkeley and at Davis, the University of Michigan, the University of Texas at Austin, and MIT. The Program has nurtured two Rhodes Scholars, two of the recent young members of the MIT Corporation, and, in May 1992, winners of MIT's Stewart Award for establishment of "Women in TPP" support group.

TPP has brought significant worldwide recognition to MIT in the field of Technology and Policy. For the 1992-93 academic year, the Program attracted about 200 applications for a class of about 35 students. The applicants have included Rhodes and Fulbright scholars, in addition to international students who have been awarded scholarships from their respective governments. Also during the past year, the Program has substantially increased its endowment of student fellowships for outstanding entering students.

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 from the UPS Foundation, in part by support from industrial and public sector sponsors, and in part by MIT.

Over 50 faculty and staff, representing all five schools, are 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, the Sloan School of Management, and the MIT Lincoln Laboratory.

STAFFING

In July, *Professor Yosef Sheffi* became the fourth director of the Center. A civil engineer by training, Yossi has spent much of his career applying mathematics, operations research, and computer science methods to innovations in transportation. He has developed models for travel demand and transit reliability, as well as for estimating vehicular flows on urban networks, advancing the state-of-the-art by introducing stochastic elements. He has developed decision support systems for motor carrier operations — many leading motor carriers now use software he developed — as well as for rail-car distribution, vehicle routing and scheduling, container positioning, terminal location, and other carrier problems. And he has worked with leading manufacturers in the US and abroad on a variety of domestic and international logistics issues — including mode and carrier selection, distribution planning, inventory/transportation trade-offs and third party logistics — developing a number of decision support systems now used by many shippers.

Joseph Sussman, the previous director, has been appointed to the JR East Professorship, a chair endowed to further transportation education and research. He is the first to be named to the chair, for a five-year renewable term. On sabbatical this past year, Professor Sussman served as a Distinguished University Scholar at IVHS America, a federal advisory group formed to advise the US Department of Transportation on IVHS matters; now back at MIT, he has been appointed head of the Transportation Systems Division of the civil engineering department.

This spring, the Center welcomed a new Deputy Director to head up the corporate Affiliates Program. Recognized for his expertise in customer satisfaction programs, and for his experience in corporate marketing strategies, *Martin Stein* holds two degrees in applied mathematics from the Sorbonne — DSc (1979) and DES with high honors (1976). He also holds two degrees in economics — an MA (1975) and a BA with high honors (1967) — from the University of Maryland College of Business and Public Administration.

David Bernstein, Assistant Professor of Civil Engineering, was named MITSUI Career Development Professor for a two-year term beginning last September. *Thomas Humphrey*, Principal Research Engineer at the Center for Transportation Studies and Lecturer in the Department of Civil Engineering, was honored this year by the New England section of the Institute of Transportation Engineers as Transportation Engineer of the Year.

RESEARCH

MIT 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, 132 sponsored, seed, and unsponsored projects were listed in the Center's *Current Research Projects in Transportation at MIT* (available upon request). Annual sponsored research volume for the Center continued its long-term growth to a level of $4.3 million in fiscal year 1991.

$9.6 Million Contract Awarded

The Center recently signed a five-year contract for $9.6 million with the Volpe National Transportation Systems Center, the research arm of the US Department of Transportation. The contract, which runs from June 1992 to June 1997, is the only open-ordering contract of its kind between MIT and a government agency. It is an agreement on the part of the Volpe Center to provide for the personnel, facilities, services, equipment and materials necessary for MIT to perform research into aspects of transportation policy and safety consistent with the Center's graduate and undergraduate education mission. While specific projects have yet to be identified, likely topics include air and other transportation operations, safety-related programs, applications of advanced computer knowledge, advanced test facilities, advanced simulators and advanced man/machine interfaces.

IVHS Program

The MIT Program in Intelligent Vehicle/Highway Systems (IVHS) is a comprehensive, coordinated effort in research, education and development involving a number of MIT's centers, labs and academic departments, as well as a range of public agencies and private companies. It is designed not only to further US capacity for traffic management, but also to improve our competitive standing internationally, vis-à-vis the major research programs currently underway in Europe and Japan. Current sponsors are Sumitomo Electric and Motorola.

At present, about a dozen faculty and research staff are directly involved in IVHS work, along with about a dozen graduate students. This spring, a new graduate subject offered by Professor *Haris Koutsopoulos*, focused on traffic flow theory and urban traffic control; the last part of the course presented IVHS concepts with emphasis on current efforts and related research issues. A number of research efforts are also getting underway on all three parts of IVHS systems — surveillance (traffic sensors, data processing, incident detection); congestion prediction (including driver behavior); and control and routing (traffic control and route guidance).

This spring, *Tony Hotz*, Staff Engineer at MIT's Lincoln Laboratory, was appointed Executive Director of the program. (Professor Moshe Ben-Akiva continues as the Program Chairman.) Hotz is dividing his hours between MIT and the Lincoln Lab, where he is heading an effort to develop and test traffic management and information systems during the construction of Boston's Central Artery project.

Transit Research

While much of our newest work is focused on IVHS and logistics, the Center continues to maintain an important effort in public transit. That effort — which now includes work force planning, service quality, operations control, service contracting, and safety — continues under the aegis of both the MBTA and the University Transportation Centers Program.

Along with the efforts mentioned above, MIT is undertaking two other important initiatives through the University Transportation Centers program which will have a significant impact on urban mobility: *The Boston Technology Coordinating Group* is a cooperative effort among transportation agencies in Boston to explore the mutual benefits of transportation system technology to deal with congestion and safety in Greater Boston. And *The New England Electronic Tolls and Traffic Management (ETTM) Initiative* is a cooperative effort among the six New England states to coordinate efforts in introducing new ETTM technologies.

Other transit research through UTC includes studies of land use and development; the high-priority needs of small and medium-sized transportation operating agencies in New England; demand responsive public transportation bus service at business centers; suburban congestion; transit for small urban and rural areas; and integrating geographic information systems technologies into transportation operations and management.

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, and over 60 students are currently working toward masters or doctorate degrees. The Center administers the interdepartmental *Master of Science in Transportation* program, whose graduates have gone on to careers with carriers, operating agencies, shippers, consulting firms and government, and into doctoral programs at MIT or elsewhere.

Fellowships

CTS continues to provide fellowship support funded by the United Parcel Service (UPS) Foundation for particularly able students at the MST and doctoral levels; the UPS Foundation endowment has been used to fund fellowships for 10 doctoral and 12 masters students. The Center also offers several summer research fellowships to juniors with interest in transportation from schools other than MIT, and provides partial support for needy graduate students in transportation.

Summer Subjects

This year, for the ninth consecutive year, a one-week summer course will be offered by Professor *Nigel Wilson* in *Public Transportation Service and Operations Planning*. In June, Professors *Richard de Neufville* and *Amedeo Odoni* offered, for the fourth time, a subject in *Airport Systems: Strategic Planning and Detailed Design*. Also in June Professor *Moshe Ben-Akiva* offered his course *Individual Choice Behavior* for the twelfth year. In August, the Center will conduct its main summer offering -- the executive course in *Logistics Analysis for Carriers and Shippers* -- which has been revamped to provide participants with some of the latest thinking on inventory, supply channel management, information technology and international logistics issues. This course is in its ninth year.

INDUSTRY AFFILIATES PROGRAM

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 success of the Affiliates Program has helped to give the Center a unique place among the dozen or so research centers in transportation at American universities, providing important opportunities for MIT faculty and students. Nine new members joined the Affiliates Program this year: Atchison, Topeka and Santa Fe; Bose Corporation; Canadian National Railways; Encompass; Flota Mercante Grancolombiana; General Electric Information Services; Roadway Services; Thomson-CSF; and the US Postal Service.

Affiliates Day

In keeping with the goals of the Affiliates Program, each year an affiliate firm hosts a day-long meeting for the other affiliates on a subject of mutual concern. Fifty-seven people attended Affiliates Day this fall at Union Pacific in Omaha for a two-day program focused on *Information Systems Support for Service Reliability*. The meeting featured presentations on UP's use of computers, which is state-of-the-art in the industry, and a tour of the nearby US Strategic Air Command Center, including a Q&A session on the logistics of Desert Storm.

Technical Seminars

Every year, the Affiliates Program sponsors several technical seminars for member firms. This year, three seminars were held. Over 100 executives were convened at MIT in February for a day-long technical seminar on a program called *JIT II*®. JIT II® is the registered service mark for a partnering and concurrent engineering program practiced by the Bose Corporation and now being implemented by a number of other US companies. In April, a seminar was sponsored in conjunction with MIT's new Transactional Data Laboratory, on *Transactional Data in Transportation*. And over forty executives attended an affiliates seminar in December, at the Executive Conference Center of the Sloan School of Management, on *Information Technology*.

THREE NEW COOPERATIVE PROGRAMS

As part of a new organizational form being implemented at MIT, the Center for Transportation Studies has joined in three new programs to coordinate and strengthen teaching and research in three different areas: *The Decision Sciences Program* (DSP), which involves the Operations Research Center, the

Laboratory for Information and Decision Systems, the Leaders for Manufacturing Program, and the Center for Computational Research in Economics and Management Science, as well as the Center for Transportation Studies. *The MIT Program in Technology, Management and Policy* (TMP), facilitating the work of several centers and laboratories, which together account for about $10 million in research funding and supervise some 200 graduate students. *The Program in Environmental Engineering Education and Research* (PEER) will explore the relationship between technology and a sustainable environment.

THE TRANSPORTATION COMPUTING LABORATORY

Under the direction of Professor Sheffi, the Transportation Computing Laboratory (TCL) is the cornerstone of computing at CTS, supporting a high level of academic and research work. The TCL supports all transportation subjects and the individual research and academic work of graduate and undergraduate students in transportation. With some additional generous support from the UPS Foundation, the TCL enjoyed substantial growth during this past year.

Apple Macintosh users benefitted from the purchase of three Macintosh IIci's and a Macintosh IIsi. These new Macs doubled the number of available workstations while providing increased storage capacity, speed, and color. For MS-DOS users, the TCL acquired two 80386/33 MHz computers, moving the lab to 386-486 class machines. Most of the DOS-based computers in the Lab now feature 386 or 486 processors. The TCL adopted a minimum configuration for our 386-class PCs: VGA color monitors, at least 4 MB of RAM, a math coprocessor, and a mouse. To meet this standard, most of the computers required upgrades; all of the TCLs 386 computers now meet this standard.

This year saw the introduction of geographical information systems (GIS) software into the TCL with the installation of Arc/Info and TransCAD. New spreadsheet, database, and presentation tools were added. To accommodate users with computationally intensive tasks, the TCL purchased a Digital DECstation 3100, which features a RISC architecture. The machine will be connected to the campus network, fostering connectivity throughout MIT and beyond.

LUNCHEON SEMINAR SERIES

Every year, the Center sponsors a luncheon seminar series featuring transportation experts from the public and private sectors, and from academia, discussing current issues in the transportation field. Open to the public-at-large, the seminars draw an audience made up of students and faculty from the Institute, and the local business, government, and academic communities. Attendance has grown substantially over the last several years as this monthly event has gained prominence on the MIT calendar and that of the local transportation community. This year's speakers were: *Richard Taylor,* Secretary of the Massachusetts Executive Office of Transportation and Construction, on the intersection of public policy and transportation technology; *Thomas Donohue,* President and Chief Executive officer of the American Trucking Associations (ATA), on the increase in transportation costs created by government actions; *Charles Wilkins,* Director of Transportation and Traffic at Ford Motor Company, on transportation supply base management and its effect on product quality; *David Gunn,* who has run the transit systems of New York City, Boston, Philadelphia and Washington, on managing public transit authorities; *Julie Belaga,* Regional Administrator of the Environmental Protection Agency, on environmental considerations in transportation planning; *Esra Bennathan,* Economic Advisor to the World Bank, on

the privatization of road haulage in Central Europe; *David LeVan,* Senior Vice President of Operating Systems and Strategies for the Consolidated Rail Corporation (Conrail), on the future of the railroad industry; and *William Spreitzer* of General Motors on the automotive industry's vision of intelligent vehicle/highway systems.

STRATEGIC PLAN

The Center is the international leader in transportation research and education. In an effort to increase that distinction further, CTS faculty has been engaged this year in a strategic planning process which will help identify the Center's strengths, weaknesses and opportunities, and will help develop a shared vision of what the Center should be. On the passenger side, CTS has a long history of research into the social, political, economic and systems considerations which should be represented in transportation planning, and in the operation of transportation systems, and that work is being continued now by a group of faculty looking at new approaches to today's and tomorrow's urban transportation problems. On the freight transportation side, CTS would like to broaden the scope of its work to make it interesting not only to carriers and to transportation professionals in shipping firms, but also to the management professionals who decide how to market the products, and the people who decide where to buy the supplies, because those are the decisions that drive the transportation decisions.

The Center for Transportation Studies right now is very much an academic research center, responding to requests-for-proposals and other directives from private and public organizations. CTS faculty would like to change this posture and position the Center as the one to define the research agenda itself, more and more — deciding what the issues are that have to be researched, convincing the funding sources these are the issues that have to be researched, and carrying out the research. CTS is also aiming to get the Center involved in being an agent of change. The Center is working with all the New England states on uniform truck permits, and with all of the toll authorities in the New England area to implement electronic toll and traffic management systems here — not only conducting research, but making things happen, going beyond the traditional role of universities.

About fifty faculty members are involved in the strategic planning exercise. It is run by a steering committee of seven, but the effort involves faculty and research staff at MIT, professionals in industry, government and academia, and our current and former students. There are subcommittees on education, research and external relations, as well as internal positioning.

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.

YOSEF SHEFFI

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 in the 60s and early 70s 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, embarked on research in clinical decision making, on the exploration of cellular automata at the borderline between physics and computation, and on the social impact of computers. At the same time, it began two major research programs in distributed systems and languages and in parallel systems. These led to the notion of data abstractions and the CLU language, the ARGUS distributed system, the dataflow principle and associated languages and architectures of parallel systems, local area ring networks, program specification and workstation development, where the laboratory contributed the earliest UNIX ports and compilers, and the Nubus architecture, now used in commercial computers, such as Apple's Macintosh II. This research has also led to the X Window System, a computer intercommunication and user interface approach, developed together with Project Athena and widely used by industry.

The laboratory's current research falls into four principal categories: Parallel Systems; Distributed Systems, Languages, and Networks; Intelligent Systems; and Theory. The principal technical goals of these four categories are as follows:

With *Parallel Systems,* we strive to harness the power and economy of numerous processors working on the same task. Research in the area involves the analysis and construction of various hardware architectures, programming languages and operating systems that yield, over a broad set of applications, cost-performance improvements of several orders of magnitude relative to single processors. This research is likely to affect most of tomorrow's machines, which we expect to be of the multiprocessor variety -- not only because of potential cost performance benefits but also because of the natural, yet unexploited, concurrency that characterizes contemporary and prospective applications, from business to sensory computing.

In the areas of *Distributed 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 and users. Such communication may involve, beyond conventional electronic mail and file transfer, the communication of programs in one environment with programs in another, perhaps different, environment; storage in persistent object-oriented repositories and the sharing of structured data among such programs; interactive use of high-quality video and sound together with text and graphics. Ultimately, we wish to establish principles and techniques for constructing and using information infrastructures from the organizational to the national level. This research is also expected to have a broad impact on future systems because virtually every machine will be connected to some network.

In the *Intelligent Systems* area, our technical goals are to understand and construct programs and construct programs and machines that have greater and more useful sensory and cognitive capabilities so that they may communicate with one another and with people toward useful ends. Examples include interactive machine understanding of spoken messages, systems that can learn from practice rather than by being explicitly programmed, and programs that reason about clinical issues and help in clinical decision making. We expect tomorrow's intelligent systems to be easier to use than today's programs, across a broad front of applications.

Taken together, these three thrusts in parallel, networked, and intelligent systems define the laboratory's overarching goal: development, understanding and better human communication with tomorrow's computer systems which we envision to be multiprocessors interconnected by networks, and information infrastructures as ubiquitous and as important as today's telephone and highway infrastructures.

In our fourth category of research, *Theory*, we strive to understand these systems and discover the fundamental forces, rules, and limits of computer science. Accordingly, theoretical work permeates many of our research efforts in the other three areas; for example, in the pursuit of parallel algorithms and in the study of fundamental properties of idealized parallel architectures and fault tolerant computer networks. Theory also touches on several predominantly abstract areas, such as the logic of programs, the inherent complexity of computations, and the use of cryptography and randomness in the formal characterization of knowledge. The impact of theoretical computer science upon our world is expected to continue its past record of improving our understanding and helping us to pursue new frontiers with new models, concepts, methods, and algorithms.

Research highlights during the reporting period are as follows:

1. Use of the Monsoon multiprocessor by the Computer Systems Group, headed by Prof. Arvind, on a large number of real problems to assess opportunities and limitations of the dataflow approach. The results of this analysis have been used in the design of *T, a commercial dataflow multiprocessor, to be fabricated by the laboratory's partner in dataflow architectures, Motorola, during 1994.

2. Substantial progress in the laboratory's other multiprocessor architectures: (1) demonstration and programming by students of a 256 node J-Machine by Prof. Dally; (2) fabrication of Alewife prototype boards; and (3) discovery of a new three dimensional interconnection scheme for the NuMesh (Prof. Ward) and (4) conversion of the CAM-8 (cellular-automation machine) design to a silicon chip (Dr. Toffoli).

3. Development of a 200 MB/s switch by Prof. Tennenhouse's group on Telemedia, Networks, and Systems.

4. Demonstration of Spoken Language Systems that can converse in and translate between English, Japanese and French, and of aids for people who are learning to read. The latter work by the learners speaking as they read and the spoken language systems tracking the process by listening and correcting the reader, as necessary.

5. In Theory, Prof. Goldwasser helped establish that an important class of problems cannot be solved by approximation techniques.

6. The laboratory under the leadership of Associate Director, A. Vezza is leading a Consortium on High Performance Computing that will bring together users, architects and algorithm designers in computability intense applications.

During this reporting period, the laboratory's Distinguished Lecturer Series included presentations by Mary Shaw, Professor, Software Engineering Institute, Carnegie Mellon University; Leonard Kleinrock, Professor and Chair of Computer Science, University of California, Los Angeles; Robert F. Sproull, Sun Microsystems, Inc.; David A. Patterson, Professor and Chair of Computer Science, University of California, Berkeley; Andrew Chi-Chih Yao, William and Edna Macaleer Professor of Engineering and Applied Sciences; Princeton University.

Changes in the administrative staff included the arrival of Helena Hughes, who joined us as Fiscal Officer, and the departures of Azi Djazani, Fiscal Officer, and Mary Mitchell, Administrative Officer.

The laboratory is organized into 16 research groups, an administrative unit, and a computer service support unit. The laboratory's membership includes a total of 437 people -- 81 faculty and research staff, 26 visitors, affiliates, and postdoctoral associates and fellows, 34 support staff, 188 graduate students, and 77 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 US Government's Defense Advanced Research Projects Agency (DARPA). The laboratory is also funded by and has extensive links with industrial organizations. These include partnerships for the construction of major hardware systems, consortia for the development and maintenance of standards, such as X Windows, and joint studies on research areas of common concern.

MICHAEL L. DERTOUZOS

Laboratory for Electromagnetic and Electronic Systems

The mission of the **Laboratory for Electromagnetic and Electronic Systems** (LEES) is to be the focus for research and teaching in electric energy from its production through its processing to its utilization, and in electromechanics from the macroscopic through the microscopic to the molecular levels. Electric energy and electromechanics are defined broadly to include power systems monitoring and operation; automatic control; power electronics; high voltage engineering; and conventional, continuum and biological electromechanics. Much of the work of the laboratory is experimental, and industrial sponsorship represents a large fraction of the laboratory's support. The laboratory's professional staff, consists of 10 faculty from EECS, 2 Senior Research Engineers,11 research staff, and 52 graduate students. The laboratory faculty and many of the staff are heavily involved in both undergraduate and graduate teaching. Faculty from the departments of ME, CE, MS&E and NE are collaborators in many of the laboratory's programs. The laboratory is also involved with the Leaders for Manufacturing Program.

ELECTROMECHANICS

Electrical Machines

Together with graduate student Mr. Derrick Cameron, Professor Jeffrey Lang has just completed the development of a computer based design package for variable reluctance motors and generators. For the generator case, the package also designs an electric power generation and distribution system specialized for use in aircraft. The package utilizes Monte Carlo design synthesis, fast numerical evaluation of performance for each synthesized design, and multi-attribute dominance to identify optimal designs from the many which are initially synthesized and analyzed. Equally important, the package evaluates manufacturability as one of its performance criteria. At MIT the package has been used to design a small electric power system that has been built and successfully tested. It has also been successfully used by the project's sponsor. A similar program directed at computer aided design of a more general class of electrical machines continues under the direction of Professor James Kirtley with support from the Leaders for Manufacturing Program. This year an improved user interface has been written, based on the Athena developed X-Window system and the Motif Widget Set. The Monte-Carlo search algorithm used by the program has been improved to make it more effective and to allow a supervisory expert system to control the design process.

Superconducting Generator

The Superconducting Generator Project, now supported by the Electric Power Research Institute, continues under the direction of Professors Kirtley and Joseph Smith (ME). The generator has achieved nearly full field current at nearly full speed operation. A nearly complete understanding of the rotor cooling circuit operation has been achieved.

Quiet Undersea Propulsion

In collaboration with and support by the Charles Stark Draper Laboratory, Professor Kirtley and his students have developed a way of injecting perturbation currents into the adjustable speed drive of a brushless DC motor to compensate for saliency induced torque nonuniformities in permanent magnet motors. This will allow quieter operation of drives used for applications such as autonomous undersea vehicles.

United States Navy

This year was the second in a planned three year research effort to develop simulation, stability analysis and control systems for the United States Navy. This year, Lt. John V. Amy Jr. finished a Ph.D. thesis in which he developed new and innovative ways of analyzing the stability characteristics of large, composite systems. In this work, Dr. Amy developed two constructs that result in a new way of estimating stability based on Lyapunov methods. The program WAVESIM, developed by Dr. Norbert Doerry last year as part of this program, has been transferred to the Naval Postgraduate School.

CONTINUUM ELECTROMECHANICS

Electron Beam Irradiation Research

In previous years Professor Markus Zahn, Dr. Chathan Cooke, and Mr. Kenneth Wright have collaborated in measuring electric field and charge density distributions in electron beam irradiated polymers using electric field dependent optical birefringence (Kerr effect). However, the measured results did not agree with accepted charge transport models, so in this past year Professor Zahn and graduate student Mr. Eugene Beidl began a collaboration with radiation experts Drs. Robb Frederickson and John Garth of the Air Force Geophysics Laboratory. They have developed a numerical computer code that for the first time includes electric field buildup in the insulating dielectric so the incoming electrons are repelled by previously trapped electrons. The numerical results are now in good agreement with measurements.

Flow Electrification

Under the supervision of Professor Zahn, and with sponsorship of the Electric Power Research Institute, graduate students Mr. Philip von Guggenberg and Mr. Andrew Washabaugh have been examining the effects of temperature and moisture on flow electrification in transformers. Temperature, moisture, conductivity and charge density sensors have been incorporated into flow electrification measurement facilities to allow continuous monitoring of relevant physical parameters important in transformers. It is anticipated that these sensors will be used in the LEES Transformer and Apparatus Monitoring project.

Magnetic Fluids

Professor Zahn has developed an electromechanical analysis to explain under what operating conditions magnetic fluids will exhibit the paradoxical behavior of pumping in the direction opposite to a traveling wave magnetic field.

MICROMECHANICS

Professor Lang, in collaboration with Professor Steven Senturia and Dr. David Volfson of the Microsystems Technology Laboratory, and graduate student Mr. Eckart Jansen, continues the development of micron scale electric motors known as micromotors. This research project is carried out in collaboration with the Case Western Reserve University (CWRU).

A new micromotor fabrication process has been developed, based on the two original processes. This new process is simplified, and permits the deposition of new materials onto the mechanically contacting surfaces within the bearings and bushings of the micromotors. This in turn permits the study of micromechanical friction and wear between surfaces coated with a variety of materials.Using the new process, micromotors have been fabricated with the standard contacting surfaces of polysilicon on either polysilicon or silicon nitride in the bearings, and polysilicon on silicon in the bushings. This represents the first successful transfer of a micromotor technology from one generation of research to the next.

It has been observed that some micromotors stick and cease operation after a period of time in a humid environment. Preliminary experiments indicate that drying the micromotors with a desiccant causes them to function again. A chamber has been developed in which micromotors can be operated in a controlled humidity and temperature environment. The operational boundary between sticking and not sticking is not a clear. Micromotors which stick while operating at one voltage can often be restarted with a greater voltage. Further, they can also often be restarted at the same voltage with a pulse from a nitrogen jet. To accommodate this characteristic of the sticking phenomenon, a statistical measure of sticking events per unit time has been developed. Data taken using this statistical measure appear to show the evolution of three operating regimes with time, which is consistent with earlier results.

A process by which optical windows can be outlined on a quartz substrate is being developed. The process will be compatible with the MIT micromotors so that the micromotors can be fabricated above the windows. The rotors of the micromotors will then become the shutters for the windows. To date, the compatibilities of platinum silicide, titanium silicide and tungsten silicide as opaque coatings on quartz have been examined. These coatings are used to outline the windows. Of these, titanium silicide appears incompatible with the present micromotor fabrication process; the others are compatible.

Together with Professor Albert P. Pisano of the University of California at Berkeley, Professor Lang is organizing the 1993 IEEE Workshop on Micro Electro Mechanical Systems. This is a leading international workshop which focuses on the analysis, design, fabrication and application of very small actuators and sensors.

BIOLOGICAL ELECTROMECHANICS AND PHYSIOLOGY

Electromechanics of Connective Tissues and Membranes

Professor Alan J. Grodzinsky and his group have continued their study of the effects of physical forces on the growth, degeneration and repair of connective tissues This research was just awarded the Ann Doner Vaughan Prize of the American Academy of Orthopaedic Surgery, a $20,000 award for Orthopaedic Research to be presented at the upcoming winter meetings of the Academy and the Orthopaedic Research Society. These studies, supported by a grant from NIH, were also presented at special plenary lectures at the recent conferences of the Combined Orthopaedic Research Societies of Japan, Canada and the US, the American College of Rheumatology, the American Society of Cell Biology, and at NIH.

A new grant from Merck focuses on identifying the mechanisms by which abnormal joint loading may induce cell production of enzymes that cause cartilage destruction in osteoarthritis as well as in normal cartilage growth and remodeling. In organ culture experiments, Professor Grodzinsky, Dr. Eliot Frank, and their students have found that stromelysin, an enzyme that is present in arthritic joints, is indeed capable of rapid, significant degradation of cartilage matrix *in vitro*. In collaboration with scientists at MGH and NIH, ongoing research is aimed at inducing repair of cartilage using proteins called

growth factors, in combination with the stimulatory effects of low frequency mechanical compression. Professor Grodzinsky, Dr. Frank, and their students, in collaboration with Brigham and Women's Hospital, continue their development of a surface sensor probe for nondestructive detection of cartilage degeneration that occurs at the earliest stages of osteoarthritis (OA). Using the late Professor James Melcher's "imposed omega-k" approach, surface electrodes deliver small currents at variable frequency and wavelength, producing a mechanical surface stress response to quantify and image tissue changes associated with OA degeneration. A submitted patent application documents this new electrokinetic spectroscopy technique.

The possibility of developing a cartilage substitute material is one of the long term goals of research involving culture of cartilage cells in a gel medium. Recent results have identified culture conditions that can lead to the development of a new cartilage-like tissue with functional physical properties; these results will shortly appear in the Journal of Orthopaedic Research. New studies focus on the mechanical function of specific matrix molecules using the techniques of molecular biology, in collaboration with researchers at Harvard Medical School.

The work of Professor Martha L. Gray and her group continues to be directed towards combining biological and physical principles to improve our understanding of connective tissue physiology and disease. The projects fall into two broad categories: (1) developing methodologies which will enhance our ability to quantitatively examine cell and tissue function; and (2) combining molecular biology and engineering approaches to characterize the role of physical forces in connective tissue growth and remodeling activity. Professor Gray was recently awarded a Presidential Young Investigator Award from NSF in support of these programs.

In the biological and clinical environment there is a frequent need to quantitatively handle and analyze small (size or volume) samples. The technology is now emerging to use microfabrication methodologies to allow the integration of micromechanical, optical and electrical components. As a paradigm for a device useful in biological settings, in collaboration with Professor Senturia, Professor Gray and her students have been pursuing a project to develop an optical flow cytometer "chip" for fluid cell and analysis. With support recently provided by an industrial sponsor, a means for hydrodynamic focusing (to ensure that cells pass through the flow chamber along a single trajectory) will be established, and the integrated waveguides which allow multi-axis optical excitation and detection will be improved.

One of the impediments to understanding the pathogenesis of arthritis has been the inability to diagnose the disease of the earliest stages and to monitor the effect of treatments on cartilage integrity. The Procter & Gamble sponsored work continues, in collaboration with Dr. Burstein of Beth Israel Hospital, to develop nondestructive NMR techniques for evaluating functionally relevant features of cartilage. The use of sodium NMR for estimating tissue fixed charge density as a reflection of tissue composition was reported and published in January 1992. More recently, NMR methods have been used to measure transport of small solutes within the matrix as an indirect measure of cartilage composition and architecture. The extension of these methods to imaging modalities offers the potential of early and non-invasive monitoring of cartilage disease.

In collaboration with Professor Lee Gehrke (HST), studies are underway to evaluate the coupled effects of mechanical forces and Interleukin-1 (IL-1) on cartilage metabolism. Interleukin-1 is a cytokine which is involved in inflammatory processes and, in particular, is believed to be involved in the mechanism of cartilage degradation in rheumatoid and perhaps, osteoarthritis. Recent results have demonstrated that IL-1 results in a close-dependent increase in the rate at which cartilage is degraded, with a commensurate decrease in the mechanical integrity. Future studies will include the application of continuous dynamic loads to see if they can reduce the deleterious effects of IL-1. These types of studies, together with the availability of a variety of IL-1 proteins (including receptor antagonists), potentially provide a means for rational design of therapeutic regimens to minimize the degradative processes in arthritis.

Electron Radiation Research

Mr. Kenneth Wright continues as physicist in the LEES High Voltage Laboratory, MIT-Lahey Clinic Radiotherapy program which started as a joint project in 1949. Part of the physics aspect of the program provides development of improved techniques for the application of megavolt x-rays and electrons to the clinical treatment of patients. During the past year a Gammamed "High Dose Rate" brachytherapy unit has been activated and used clinically by the Lahey Clinic. At present it is being used primarily for lung tumors but will be used to supplement the dose delivered by external beam radiation to the primary tumor of other tumor sites. A project carried out in cooperation with Professor Peggy Cebe's group in the MS&E Department was concerned with long-term radiation damage studies of materials used in space. High dose rates were required to enable delivery of a dose in a reasonable time equal to that estimated to be received by the material in thirty years in space.

Blood Analyzer

In connection with the joint ME, EECS, and Sloan School New Products Program, Mr. David Otten is collaborating with Dr. Michael Rosen of the ME Department and Professor William Qualls of the Sloan School to develop a technologically innovative blood analyzer for Becton Dickinson. A project team with expertise in Mechanical Engineering, Electrical Engineering, Optics, and Marketing is working on the project. The purpose of the project is to teach both the students and the sponsor modern integrated product design processes using as a context a particular project of the sponsor. The group is required to produce a prototype of the instrument at the end of 2 years.

HIGH VOLTAGE AND INSULATION RESEARCH

Professor Zahn with graduate student Mr. David Brown has developed a well-monitored test cell for optical measurements of the electric field and charge density distributions in high voltage stressed solid/liquid dielectric structures. This test cell incorporates sensors for continuous monitoring of conductivity and moisture so that the dielectric state can be completely characterized. Preliminary measurements have related the electric field and charge density in transformer oil as a function of temperature, moisture, and conductivity.

Professor Zahn and graduate student Karen Walrath have been developing a microwave method for detecting moisture and water trees in polyethylene power cables. Microwave absorption measurements are being done in a polyethylene cable submerged under water that is high voltage stressed and growing water trees. A method to measure the spatial distribution of water trees is also being prepared in a dielectric waveguide structure within a metal waveguide using evanescent waves in an analogous way to the use of infra-red light with attenuated total reflectance (ATR).

Dr. Chathan Cooke and Mr. Wright continue to use electro-acoustic methods for studying charge distribution and the resultant electric fields produced by the injection of electrons into certain solid dielectrics such as PMMA (Lucite, Plexiglas, etc.). Since PMMA is one of the materials which is used as phantom material with ionization chambers in radiation dosimetry measurements, any errors caused by electron trapping should be known in order to improve the accuracy of dose delivery. Undergraduate Mr. Charles Yu has been studying the injected charge distribution as a function of beam energy, integrated incident electron flux and decay with time at clinical dose levels. Measurements of these levels of charge trapping provide additional information not available in the Kerr electro-optical studies carried out in cooperation with Professor Zahn's group.

POWER ELECTRONICS

Professors John Kassakian, George Verghese, and Martin Schlecht lead the laboratory's teaching and research activities in power electronics. Recent emphasis has been placed on the areas of modeling and adaptive control, manufacturing technologies, new integrated power supply concepts, and very high power density converter concepts.

Various random modulation scheme have been implemented by several groups in the US and Japan, with the aim of shaping the harmonic content of switching noise to meet stringent new standards, but none of these schemes had been satisfactorily analyzed or explained. Professor Verghese and his students have, over the past year, provided a theoretical analysis of each of these implementations, as well as other possible ones, and have verified their analyses with Monte Carlo simulations.

A collaboration between Professor Verghese and Professor Kato of Doshisha University in Japan has resulted in a very efficient method of numerical determination of the boundaries between operating modes in a power converter. The method has been demonstrated on a clamped-mode resonant converter that exhibits complicated behavior. This has led to further investigations of the modeling and control of this sort of converter. Professor Verghese and his students have also demonstrated digital control of a high-power-factor converter in a project funded by the Digital Equipment Corporation. The results of this project are drawing attention to the potential for digital control.

Work on an advanced front-end converter for a distributed power supply has been completed under the supervision of Professor Schlecht and with the support of IBM. This converter, which provides power factor correction and an isolation/step-down stage, dissipates half the energy that a standard commercial product does, yet has roughly the same cost. This advantage was achieved by using interleaving, a technique where multiple low power cells are connected in parallel, but have their switching instants phased uniformly relative to each other throughout the fundamental period. In a project sponsored by the Draper Laboratories, Professor Schlecht created a high frequency (1 MHz), high density ($40W/in^3$) power supply having three outputs (5V, $\pm$ 10V) at a total of 20W. The requirement of this supply was to have very low differential and common-mode ripple so that it could be used for ultra-sensitive analog circuits. Professor Schlecht has also proposed a new, low loss, approach to the design of logic circuits which integrates the power supply and logic element. Simulations show a potential savings of 80 percent of the power normally dissipated in a CMOS circuit operating at 30 MHz.

POWER SYSTEM PLANNING AND OPERATION

Drs. Marija Ilic and Richard Tabors provide the focal point for research and teaching activities in power systems planning and operations. During the past year additional contributions in research and teaching were provided by Professors Kirtley and George Verghese as well as Mr. Wayne Hagman. The Third MIT Workshop on Power System Research at MIT was held in October 1991. The power systems group within LEES worked cooperatively with faculty from the American University of Beirut (AUB) in an evaluation of the reconstruction of the Lebanese power system. Two students from AUB spent the fall semester at MIT working with two AUB project supported MIT students and with the faculty.

Drs. Tabors and Ilic taught 6.683, Introduction to Power Systems Operations and Planning, to the largest and most varied group of graduate students since the initiation of the course, drawing students from EECS, Ocean Engineering, Mechanical Engineering, Nuclear Engineering, the Technology and Policy Program (TPP) and the Kennedy School of Government at Harvard. An output of student/faculty work initiated during the course is a paper to be presented at the IEEE Summer Power Meeting in July 1992 on the economics/pricing of transmission system operations.

Research work on the development of algorithms for optimal, automated control of transmission systems during emergency conditions was continued under funding from both US and French electric utilities. The project is investigating nonlinear excitation control of generators when the power system is subject to large-signal changes. The general concept developed under this project is applicable to other types of fast controllers on power systems, such as static VAR compensators. Dr. Ilic presented a invited paper on the state-of-the-art of voltage control methods and the potential of flexible ac transmission systems (FACTS).

Under sponsorship by Electricite de France (EdF), Dr. Ilic, in collaboration with EdF Visiting Scientist Dr. Christine Vialas, is working on providing a new concept for on-line automated coordination of voltage regulation in separate geographical regions. This coordination will be carried out by the French national control center in Paris. The coordination concept under development in this project is potentially applicable to controlling any large-scale discrete event process, and therefore has generated substantial excitement.

SYSTEMS IDENTIFICATION AND CONTROL

Professor Verghese and his student have developed a systematic methodology for decomposition of parameter estimation problems, to take account of computational constraints, to improve convergence rates, and to separate ill-conditioned parameters from well-conditioned ones. These results are developed in the doctoral thesis of Mr. Miguel Velez-Reyes, and their application to speed and parameter estimation in induction machines has led to new insights and major performance improvements over several previous efforts.

TRANSFORMER AND APPARATUS MONITORING

The laboratory continues to advance the art of performance monitoring of large power transformers. This work includes monitoring system software architecture design and implementation, sensor and sensing system development, and investigation of the response of transformer performance signatures to normal and abnormal operational conditions. This past year, we have had two visitors working specifically in transformer monitoring. Dr. No-Hong Kwak, of the Korea Electric Power Company, and Mr. Brian D. Gemmell, a graduate student from the University of Strathclyde, Scotland.

Ultrasound

Dr. Chathan Cooke has continued his sensitive ESAW (Electrically Stimulated Acoustic Wave) method measurements and has been applying them to the evaluation of the degradation of paper insulation used in power transformers. In this work the ultrasonic acoustic properties of paper are being compared to measured mechanical strength for various amounts of thermal aging. The results indicate that end of life can be predicted by determining the time where there is a 50% reduction in strength. Dr. Cooke has also applied the ESAW method to determine internal electric stresses within extruded high voltage power cables. Initial studies have shown that internal charges accumulate within power cables and the rate of accumulation is dependent on the applied voltage. ESAW measurements are proceeding to stresses at the 100kV level. The results obtained are being used to determine conditions and materials that limit the operating life of power cable systems.

Dr. Cooke, in collaboration with Professor Jin Kong, has been exploiting acoustic time domain reflectometry to examine the reflection of pulsed incident acoustic waves from spatially distributed interfaces. The work has produced movie-like displays of these wave interactions and analysis has shown that considerable spatial information can be recovered when pulse widths are comparable to or less than the size of the spatial variation at the interface. An application of this work is non-destructive diagnosis, for example to assess the corrosion or wear condition of internal surfaces of pipes or containers.

Non-destructive Breakdown Measurements of Oil Dielectrics
This project is co-supervised by Dr. Cooke and Mr. Wayne Hagman, and involves the development of an *in situ* method for determining the dielectric strength of oils in electric power apparatus. This year the studies were used to quantify the sensitivity of the test to moisture and particle contamination in the oil. The results of the MIT test are being compared to two ASTM standard oil breakdown tests to ensure compatibility of the NDBD method.

MIT Adaptive Transformer Monitoring System
The work on monitoring system software architecture design and implementation is led by Mr. Wayne H. Hagman, and is directed at the achievement of automated analysis of trends in transformer performance. Undergraduate student Ms. Laura E. Edwards developed the second generation MIT Adaptive Transformer Monitoring System. She has solved an important problem concerning the accurate on-line estimation of parameters for dynamic models that represent a transformer. These results pave the way for automated analysis of long-term trends in transformer performance.

Electromechanical Monitoring of Motor Operated Valves
This project involves Mr. Hagman, Prof. Lang, and Dr. Steven Umans of LEES, and Professor Richard Lyon of the MIT Acoustics, Vibration, and Machine Dynamics Laboratory. Motor operated valves (MOV's) are a major source of failures in nuclear power plants. This project applies adaptive model-based monitoring concepts to the operation of MOV's. The method employs non-invasive measurements of motor voltage and current, and drive train vibration, to predict, through the use of dynamic models, valve opening and closing torque, and valve and drive train condition. Results achieved during the past year include the development of a motor torque estimator based on measurements of voltage and current, and of a dynamic electromechanical model of the motor operator, including the torque estimator and transmission components, to allow the determination of valve stem position and force.

MAGLEV TECHNOLOGY

Professor Richard Thornton and his group are performing research on maglev transportation technology as part of the National Maglev Initiative. LEES researchers are active both independently and in collaboration with a team consisting of MIT, Draper Laboratories, General Motors, Bechtel, and Hughes. Professor Thornton has taken a leadership role in guiding this research towards an effective and practical maglev system. He has hosted a year-long seminar series at MIT under the National Maglev Initiative the objective of which has been to bring together researchers on maglev technology and serve as a forum for the exchange and development of ideas. Currently under way in LEES is the development of low cost linear synchronous motor (LSM) propulsion systems for maglev. This research is focussed on the design of the linear motor and the power distribution and conversion equipment, with an emphasis on low cost and fault tolerance. In addition to analytical and computational work, a 1/25th scale LSM propulsion system has been constructed and is currently in use. This experimental setup allows verification of theoretical results, as well as the development of appropriate sensing and control techniques. A joint project in collaboration with researchers in the Civil Engineering Department has been the development of low-cost guideways for maglev using narrow beams. The potential for use of nonmagnetic reinforcing materials, such as fiberglass reinforced plastic (frp), has been investigated. Testing of concrete beams reinforced with hybrid frp rods has been performed, and programs for cost and sensitivity analyses of such systems have been developed.

MANAGEMENT OF TECHNOLOGY

Professor Thomas Lee, a former Director of LEES, who founded the independent Center for Quality Management in 1989, has been responsible for introducing the concept of Total Quality Management (TQM) to both MIT's curriculum and its operations. During the past year he co-chaired the first MIT Conference on TQM, and is active on the Governor's Council on Quality and a member of the Dean of Engineering's Committee on Large Systems.

EASTERN EUROPEAN INITIATIVE

Professor Kassakian and Dr. Tabors have initiated an industrial mission to Czechoslovakia to provide a technology interface between US industries and newly created Czech and Slovak companies. This activity is a precursor to a more comprehensive role for MIT in the processes of industrial change taking place in the newly democratized nations of East and Central Europe.

John G. Kassakian

Laboratory for Information and Decision Systems

The Laboratory for Information and Decision Systems (LIDS) is an interdepartmental research laboratory of the Massachusetts Institute of Technology. Its staff includes faculty members, full-time research scientists, postdoctoral fellows, graduate research assistants, and support personnel. Undergraduate students participate in the research program of the Laboratory through the Undergraduate Research Opportunities Program (UROP). Every year several research scientists from various parts of the world visit the Laboratory to participate in its research program.

The fundamental research goal of the Laboratory is to advance the field of systems, communication and control. In doing this, it explicitly recognizes the interdependence of these fields and the fundamental role that computers and computation play in this research. The Laboratory is conducting basic theoretical studies in communication and control, and is committed to advancing the state of knowledge of technologically important areas.

As an interdepartmental laboratory, LIDS reports to the Dean of the School of Engineering, Professor Joel Moses. The Co-Directors of the Laboratory are Robert G. Gallager, Fujitsu Professor of Electrical Engineering, and Sanjoy K. Mitter, Professor of Electrical Engineering.

The Center for Intelligent Control Systems (CICS), an inter-university, interdisciplinary research center operated by a consortium of Brown University, Harvard University and MIT, resides administratively within the Laboratory for Information and Decision Systems.

Twenty-eight faculty members, several research staff members and approximately 75 graduate students are presently associated with the Laboratory and the Center. Currently, the Laboratory and the Center provide some 50 research assistantships to graduate students. Undergraduate students also participate in research and thesis activities. A number of postdoctoral and visiting appointments are also made.

Financial support is provided by the National Science Foundation, NASA, the University Research Initiative Program (Army Research Office), Defence Advanced Research Projects Agency (DARPA), IBM, the C.S. Draper Laboratory, the Office of Naval Research, and the Air Force Office of Scientific Research.

NEW RESEARCH INITIATIVES

Consortium on Wideband All Optical Networks

Researchers from LIDS, RLE, Lincoln Laboratories, AT&T Bell Laboratories and Digital Equipment Corporation have been collaborating for the past year in developing a consortium on all optical networks. Initial funding for the consortium is to be provided by DARPA and is in the final stages of contract negotiation. The goal of the consortium is to pursue research and development on the optical technologies, the architectures, and the application interfaces required for a scalable, universal, wide area, wide band, all optical network. A key element of the consortium's work is the construction of an extensive test bed linking the consortium members and demonstrating the feasibility of the design concepts. The DARPA support is for two years and is focussed on the test bed, but the consortium is viewed as a long term effort paving the way to the national and international information infrastructures of the future. Professors Gallager, Humblet, Kennedy, Dr. Steven Finn, and a number of graduate students are involved in the consortium.

Coordination in Large Organizations

A new project funded by NSF and involving collaboration with researchers from the University of Connecticut started this year under the direction of Professor Michael Athans. The goal of this project is to develop normative/descriptive models of small and large organizations in which the decision-makers do not have identical information. The paradigm of distributed hypothesis testing is used to assess the performance of different organizational architectures, for both optimal and suboptimal decision rules, and the development of adaptive training algorithms for the organization as a whole.

Dynamic Control of Large Space Systems

A new set of projects involving issues of robust and decentralized control for large space structures was initiated this year by Professor Athans and several students. The research involves significant interactions with faculty and staff from the MIT Space Engineering Research Center and staff from the C.S. Draper Laboratory, Inc. In addition to theoretical research, designs of multivariable control systems for a space-based interferometer testbed and a computer model of a space-based laser are being carried out.

Identification and Adaptive Control

Determining the fundamental limitations and capabilities of identification and adaptive control has become an active area of research carried out by Professors Munther Dahleh, John Tsitsiklis and Sanjoy Mitter and their students. This newly

initiated research program draws upon areas such as information-based complexity theory and computational learning theory as well as upon the theory of robust control.

Machine Learning

In recent years there has been a great deal of interest in the theoretical foundations of machine learning. One goal of this work is to identify the limits of what is and is not possible, such as information theory does for communications or the theory of computation does for computing. One particular framework that has received much attention is a distribution-free model often referred to as the Probably Approximately Correct learning model. The focus of research in LIDS is on analyzing such learning frameworks with a view towards extending their domain of applicability into areas such as machine vision and system identification. Professors Sanjoy Mitter and John Tsitsiklis and their students are involved in this work.

CURRENT RESEARCH

Multi-Resolution Statistical Signal Processing

For some time now there has been considerable interest in algorithms for the processing of signals or images that examine data at multiple resolutions. In the recent past, a theory involving the so-called "wavelet transform" has been developed for the deterministic representation of signals at multiple resolutions, and this has sparked a considerable response from the research community in exploring potential applications in a variety of areas ranging from computer vision to the fusion of multispectral measurements. An essential element in the development of a systematic methodology for the design of multiscale algorithms is the development of a statistical theory for multi-resolution signals. Efforts to develop such a theory are underway by Professor Alan Willsky at LIDS together with a group of researchers in Rennes, France. The initial results that have been obtained, together with the considerable attention this topic is receiving from the research community lead us to believe that this will be an extremely fruitful area for some years to come.

Three-Dimensional Structure Determination

Problems of three-dimensional chemical structure determination provide several test-bed problems for three-dimensional random field estimation which are simultaneously of great intrinsic importance. Solution of these problems is crucial to the understanding of natural biological molecules and for the engineering of novel new modified molecules--catalysts for industrial processes, drugs, and so forth. Furthermore, this is currently a field of intense interest in chemistry and biology with many eager collaborators within MIT. Finally, the understanding developed by studying these three-dimensional problems will transfer to other three-dimensional problems such a signal processing for sequences of images and atmospheric/oceanographic/seismic sensing with detailed, and therefore, three-dimensional, models. To address these problems, a research program involving Professor Sanjoy Mitter and Professor Alan Willsky is ongoing.

Data Communication Networks

Research in Communication Science and Systems ranges from basic information theoretical studies of networks and communication channels to the architectural design of network protocols. The major objective of this work is to develop the scientific base needed to design data communication networks that are efficient, robust, and architecturally clean. Both wide area and local area networks, both high speed and low speed networks, and both point-to-point and broadcast communication channels are of concern. Some of the topics in this area are multiaccess communication processes, routing, congestion control, diverse traffic mixes, the communication complexity and delay of distributed algorithms, failure recovery, and topological design. Professors Dimitri Bertsekas, Robert Gallager, and Pierre Humblet are conducting this research.

Fiber Optic Communication Networks

The goal of this work is to identify and resolve the new fundamental network design issues that arise when very broadband optical fiber technology is used. It differs from past network research in that the emphasis is upon effective utilization of the enormous excess bandwidth that this technology makes available rather than upon minimizing the bandwidth the network requires. In the bandwidth-rich situations addressed by this work, the usefulness of such traditional bandwidth conserving techniques as switching and packetization must be re-examined. Professors Pierre Humblet and Robert Kennedy are conducting this research which includes theoretical and experimental components.

Estimation, Statistical Signal Processing, and Inverse Problems

A variety of stochastic estimation, analysis and signal processing problems are being studied by Professors Sanjoy Mitter, George Verghese, and Alan Willsky and their students. Theoretical studies are conducted in the areas of estimation algorithms for spatially distributed random processes, nonlinear filtering, relationships among filtering problems in scattering theory, and the analysis of large-scale systems subject to a variety of very rare events. Complementing this theoretical research are more applied projects, including the design of algorithms for detecting and compensating for sensor or actuator failures, and the development of model-based signal processing algorithms. The specific signal processing problems include the diagnosis of arrhythmias in electrocardiograms, the detection of objects or anomalies given

tomographic measurements such as those made using X-rays or ultrasound in medical and industrial nondestructive testing applications or in laser radar imaging systems, the analysis and inversion of spatially-distributed geophysical data, image processing and understanding, and computational vision.

Discrete-Event Dynamic Systems
During the past few years there has been considerable interest in the development of control concepts and algorithms for complex processes that are characterized more by the occurrence of discrete events than by differential equations representing the laws of physics. Such processes are typically man-made--flexible manufacturing systems, computer networks, etc.--and are often best described in symbolic, rather than numeric form. Professor Willsky's a research is aimed at combining concepts from computer science and from control in order to develop a meaningful theory of control of such systems. In particular, the models and formalisms used in such a study come from the field of computer science (automata, synchronous processes, etc.), while the problems and design paradigms come from control (stability, regulation, robustness,...). The results to be obtained from this study should be of value in such diverse applications as distributed database management and flexible manufacturing.

Multivariable and Adaptive Control
Systematic design of multiple-input-multiple-output systems, using a unified time-domain and frequency-domain framework is an extremely active research area in the Laboratory. Various theoretical and applied studies are being carried out by Professors Michael Athans, Munther Dahleh, Sanjoy Mitter, Gunter Stein and Lena Valavani and their students. Theoretical research deals with issues of robustness, aggregation, and adaptive control. Recent application-oriented studies include the control of large space structures, helicopters, submarine control systems, engine control system designs, and issues of integrated flight control.

Deterministic and Stochastic Nonlinear Dynamical Systems
The theory of nonlinear systems, both deterministic and stochastic, has developed rapidly during the last ten years. There is increasing interest in deterministic nonlinear control and various problems of adaptive control which lead to problems of nonlinear control. In the context of stochastic dynamical systems, problems of the qualitative behavior of such systems under different time-scales are of great interest. Recent work on nonlinear filtering has shown a relationship to infinite-dimensional, bilinear systems, and there is increasing interest in the understanding of qualitative behavior of nonlinear filters for large and small time-intervals. Finally, research is under way on the subject of control of discrete-event systems. Various investigations in this area are being conducted by Professors Michael Athans, Sanjoy Mitter, John Tsitsiklis, George Verghese, Alan Willsky and their students.

Theory and Algorithms for Optimization
This project focuses on analytical and computational methods for solving broad classes of optimization problems arising in engineering and operations research, as well as for applications in communication networks, control theory, power systems, computer-aided manufacturing and other areas. Currently, in addition to traditional subjects in nonlinear and dynamic programming, there is an emphasis on solution of large-scale problems involving network flows as well as in the application of decomposition methods. The thrust is twofold: first, to find ways to handle the typically huge number of constraints; second, to explore the use of distributed and parallel processing to reduce the computation time needed to solve a problem and to economize on information transfer from remote data collection points to a computation center. This gives rise to fundamental issues involving the synchronization of computation and communication that are as of yet only partially resolved. Professors Dimitri Bertsekas and John Tsitsiklis and their students perform this work.

The Nematode as a Model Complex System
Dr. Charles Rockland and Professor Sanjoy Mitter, joined by Mr. Steve Rowley, have continued work on this project. This work has included setting up some of the general software framework, "structures" and "models," which in particular associate dynamics to the structures. An initial implementation of this framework, carried out on Symbolics Lisp machines, has been applied to some motor nervous system models.

Information Transfer and Retrieval
Research on information transfer retrieval focuses on making interaction with computer based information systems easier and more effective for human users. This research is supervised by Mr. Richard S. Marcus. A current project involves the development and testing of an expert computer retrieval assistant that should help make searching a quantified science rather than an informal art through proper structuring of, and operations on, verbal descriptions of database objects. These objectives are to be obtained through such (semi) automated techniques as (1) derivation of a conceptual formulation of a user's problem and its translation into an initial search strategy; (2) ranking by estimated relevance of documents retrieved thereby; and (3) analysis of user relevance feedback to (a) estimate the number of relevant documents not yet retrieved and (b) reformulate the search strategy to retrieve those missing nuggets. Experiments with a precursor to the expert system have already demonstrated retrieval effectiveness, in terms of numbers of relevant documents found, equivalent to that achievable by human information specialist acting as a search assistant. Partly based on this research, a series of operational and retrieval assistant systems have been developed.

System, Reliability and Risk Management

Research on risk assessment and management is carried out in many MIT departments and laboratories. At LIDS there is interest in describing the reliability of complex systems in terms of what is known about the reliability of their components. Professor Alvin Drake has supervised research on the development of models and algorithms for studying the manner in which uncertainties about component reliabilities are reflected in uncertainty about system reliability. The primary area of application has been to low probability, high consequence risks in nuclear reactor safety. Professor Drake is also concerned with probability assessment, particularly the quantification of expert judgment. A current project is detailed probabilistic analysis of the sequence of tests used to screen donated blood for the presence of AIDS-associated antibodies.

Center for Intelligent Control Systems

The Center for Intelligent Control Systems (CICS) combines distinguished faculty from MIT, Harvard University and Brown University in interdisciplinary research on the foundations of intelligent machines and intelligent control systems. Established in October 1986, CICS is headed by Professor Sanjoy Mitter, Director; Professor Roger Brockett, Harvard University, Associate Director; and Professor Donald McClure, Brown University, Associate Director. The research activities of the Center are loosely grouped into five areas: Signal Processing, Image Analysis and Vision; Automatic Control; Mathematical Foundations of Machine Intelligence; Distributed Information and Control Systems; and, Algorithms and Architectures . A number of outstanding graduate students are appointed Graduate Fellows. The Center also hosts several senior visitors for varying lengths of time each year. Continuation funding has been received.

Speakers in the 1991/92 CICS Colloquium Series included: Prof. R.E. Kalman of the Swiss Federal Institute of Technology, Prof. Shankar Sastry of the University of California at Berkeley, Dr. G. David Forney, Vice-President of Motorola based at Codex Corporation, Prof. Thomas Kailath, Stanford University and Dr. James Massey, Institute for Signal and Information Processing, Eth-Zentrum, Zurich.

VISITORS TO THE LABORATORY

Among the visitors this year were: Dr. Ofer Zeitouni, Technion, Prof. Thomas Kailath, Stanford University, Dr. Steve Finn, Chairman and Vice-President Business Planning and Development, Bytex Corporation, Prof. Roland Dobrushin, USSR Prof. John Baillieul, Boston University.

HIGHLIGHTS

Professor Robert G. Gallager was elected to the National Academy of Sciences in recognition of his "distinguished and continuing achievements in original research."

Professor Alan Willsky gave the Keynote Address at the IEEE Int'l Conference on Systems Engineering, Dayton, OH, August 1991, was one of the lead invited lecturers at the SIAM Conference on Applied Linear Algebra, Minneapolis, September 1991, and was a featured invited lecturer on Multiresolution Methods in Image Analysis at the Tri-Service Workshop on Statistical Methods in Image Processing, May 1992. Prof. Willsky gave keynote address at the inaugural workshop for the Centre for Robust and Adaptive Systems, Canberra, Australia, February, 1992. He was Guest Editor of the IEEE Transactions on Information Theory for a special issue on Wavelet Transfer and Multiresolution Signal Analysis, scheduled for February 1992. Also, Prof. Willsky's work Under AFOSR Sponsorship was highlighted in AFOSR's annual report to Congress.

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 conduct engineering research in manufacturing and to develop the fundamentals of manufacturing science. The primary research focus is on the analysis, design, and control of manufacturing processes. Rather than concentrating on methods of coping with existing complex manufacturing systems, our long term goal is to reduce the inherent complexity of manufacturing through a combination of process innovation and development of new fundamental principles for manufacturing science. In this way we seek both to improve the understanding of present manufacturing technology and to generate new methods and machines that will potentially restructure the entire enterprise of manufacturing. 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 curricula used to educate engineers in the field of manufacturing. Several 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 not only an advanced understanding of physical processes but also an interdisciplinary proficiency.

As an interdepartmental laboratory, the LMP reports to the Dean of the School of Engineering, Professor Joel Moses. David Hardt, Leaders for Manufacturing Professor of Mechanical Engineering, serves as Director, Dr. Andre Sharon serves as Associate Director, and Ms. Sally Stiffler serves as Assistant Director for Administration.

Since it is virtually impossible to address issues in manufacturing without considering the needs of industry, it is crucial that close ties between the Laboratory and manufacturing companies be maintained. In fact, over 50 percent of the research conducted in the LMP is sponsored by industry. Many of the sponsoring companies participate in our industry consortia, which include the Composite and Polymer Processing Program, the Tribology Program, the Microcellular Plastics Program, and the 3-D Printing Consortium. Further technology transfer is facilitated by the LMP Industrial Collegium, presently comprised of over 35 companies with a common interest in manufacturing. The collegium serves as an information channel between industry and the LMP, and is administered by Mr. John Keene who serves as Coordinator of the Collegium.

RESEARCH AREAS

Research activities in the LMP encompass the following areas:

- Process Innovation
- Flexible Automation and Process Control
- Precision Engineering
- Tribology
- Scheduling and Production Planning
- Design/manufacturing integration

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. Current projects in this area include novel methods of fabricating composites, polymer processing, spray forming of metal-matrix composites, microcellular plastics, laser machining, and three dimensional printing.

Flexible Automation and Process Control

Flexible automation can greatly increase the cost-effectiveness of a process. It can facilitate product changes with minimal retooling and change-over time. It is our goal to extend the capabilities of flexible automation through novel hardware, software, and control strategies. Process 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 flexible automation of composites materials, robotics, real-time control of welding processes, and real-time control of metal forming processes.

Precision Engineering
Precision engineering is the study of ways to make machines and components more accurate without a substantial cost increase. In this definition, it must be remembered that speed, force, temperature, and many other parameters act to decrease the accuracy of a machine. Thus by its very nature, precision engineering is a multidisciplinary field.

Ongoing projects include the development of high-precision machine components (such as ceramic bearings, spindles, ball-screws, etc.) that will facilitate development of high-precision machines.

Tribology
Tribology is providing a better understanding of wear mechanisms, which in turn leads to a more predictable and reliable product. Ongoing projects at the LMP are exploring wear mechanisms in various applications, including magnetic recording media, electrical contacts, and piston-cylinder interaction in internal combustion engines.

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 modeling and "optimally" scheduling the flow of products through manufacturing lines.

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.

NEW APPOINTMENTS

Dr. Alexander Slocum has joined the LMP in September, 1991 as Assistant Professor of Mechanical Engineering. Professor Slocum conducts research in precision engineering and machine design. His research has lead to the development of ingenious designs, such as a self-coupling hydrostatic leadscrew, an atomic resolution measuring machine, and an accelerometer calibration machine.

Professor Slocum, a former member of the MIT faculty in the Department of Civil Engineering, spent five years on the MIT faculty, and one year at the Cranfield Institute of Technology. He received his B.S., S.M., and Ph.D. in mechanical engineering from MIT and was named Presidential Young Investigator in 1988. He holds 9 patents and has written a textbook, *Precision Machine Design*, which promises to become the standard textbook for teaching precision (and nano-) machine design. In July 1992 he was promoted to Associate Professor of Mechanical Engineering.

NEW INITIATIVES

Precision Engineering
Historically, technological breakthroughs are often preceded by new materials advances. Currently, because of their inherent temperature invariability, ceramics are proving to be ideal materials for high accuracy applications. High precision ceramic parts will revolutionize the consumer products industry (e.g., better bearings, more precise disk drives, better integrated circuits). In order to process precision ceramic parts, however, we need to develop a new generation of high-precision tools.

This effort is a collaboration between faculty in tribology, control systems and heat transfer. What is being developed is, in effect, a new form of machine design research and education, where the goal is to create engineers who will bring a new standard of excellence to this vital and usually overlooked aspect of

manufacturing. This "excellence" is driven by the relentless demand for precision, and the complexity of the engineering problems that such precision presents.

In this area we have begun developing a network of industrial partners that will allow us to access state of the art design information and production expertise.

Manufacturing Institute
Professor Nam Suh and Dr. Andre Sharon of the LMP have founded the Manufacturing Institute at MIT. The Manufacturing Institute is an advanced technology development center with the mission of

enhancing the competitive position of U.S. industry by accelerating the process of turning research concepts into usable technologies and products.

A primary goal of the Manufacturing Institute is to help small manufacturing companies in the U.S. Through U.S. Senator John Kerry's office and the Bay State Center for Applied Technology, we have established contact and are currently working with a group of small metal stamping shops to develop technologies that are especially suitable for small companies. With the Manufacturing Institute as a focal point, we are forming alliances between groups of small manufacturing companies, MIT, the state, and the federal government. These alliances will facilitate the development of technologies that are directly applicable to the needs of small manufacturers.

We are also undertaking technology studies for large companies to assess the feasibility and cost benefits of potential technologies applied to their business needs. These technology studies will lead to large-scale technology development contracts.

Droplet-Based Manufacturing Research Program
Professor Jung-Hoon Chun of the LMP recently established a research program in Droplet-Based Manufacturing (DBM). DBM is directly applicable to many strategic manufacturing processes including spray forming, spray coating, direct forming of 3-D parts, production of uniform metal powders, spray welding, and production of high performance materials. The objectives of this research program are to study the basic principles of DBM processes, to establish a knowledge base that can be applied to the rational design and control of DBM processes, and to promote mutually beneficial interaction between industrial firms and the Program.

Design and Control of Atomic Resolution Systems for Increased Data Storage Capacity
Professor Kamal Youcef-Toumi of the LMP has received a Mechanical Engineering Department Grant to investigate the potential of atomic resolution motion in data storage systems. Data storage systems are vital for many products. This research proposes a new approach which increases data storage capacity by several Gbytes in less than 1/3 of an inch diameter disk using the technologies of Scanning Tunneling Microscope and the Magnetic Force microscope, thus enabling access to atomic-size information. This is about 10 - 20 times the capacity of the 5 inch CD ROM. The advantages of the proposed system over others are its ability to both read and write information at high access speeds, providing strong anti-vibration and low energy consumption, and its low production cost.

Besides its potential technological breakthrough, this project leads the way for the LMP to become a contributor to the field of microelectronics rather than just a user.

DAVID E. HARDT
ANDRE SHARON

SUSTAINABILITY

Now beginning its fifth year, the Leaders Program has successfully completed its initial, experimental phase. It has proven the effectiveness of a true industry-academia partnership that emphasizes long-term working relationships between engineering and management faculty and company people for both educating young people to lead manufacturing organizations in a global marketplace and generating more "pull" for research within companies.

The program is therefore transitioning from the pilot phase to a phase of self-sustainability, growth, and expanded horizons. LFM is halfway to its goal of recruiting four more partner companies: Intel Corporation joined LFM in February 1992 and Ford Motor Company joined in May. LFM partner company representatives have been closely involved throughout the sustainability efforts, volunteering their understanding of which companies might be most valuable to the partnership, who to contact and how, and many times following up themselves with the prospect companies.

Another move toward self-sustainability involves student support, as an eventual goal is for less student support to be required from the program. The past year's classes of nonsponsored fellows were granted a monthly stipend (first-year students) and research assistantships (second-year students) with the written expectation that they would join a manufacturing firm upon graduation; LFM has also been awarding *all* fellows' tuition, regardless of company sponsorship. The program this year is offering financial aid for tuition and stipend as loans that are forgivable if the students join a United States manufacturing firm at graduation and continue working in manufacturing for the next four years; students' loans are combined with research assistantships during their second year. The long-term plan is for up to half of the LFM fellows each year to receive tuition and stipend support directly through the partner companies' sponsor programs. During fiscal year 1992, eight LFM fellows were funded by sources outside the Leaders Program and its partner companies (e.g., Robert N. Noyce, National Science Foundation, and National Consortium for Graduate Degrees for Minorities in Engineering and Science, Inc., fellowships).

Accommodations for Program Growth

The second floor of Building E40 has been renovated to provide carrel space for 22 LFM students, bringing the total number of carrels to 98 for accommodating during spring term 85 fellows this year, and approximately 100 eventually. The second-floor renovation also provides office space for three of the program's management staff and two others (in 1991–92, Professor Shoji Shiba, a visiting professor renowned in the area of total quality management, to teach the fellows TQM concepts and techniques; research scientist Ashraf Alkhairy; and Professor Ram Akella, visiting from Carnegie Mellon University).

Grants

The LFM total quality management emphasis has inspired MIT to participate in industry's "TQM University Challenge": a challenge to universities to integrate TQM principles and concepts into management and engineering curricula and the universities' administrative processes. The Institute's proposal for meeting the challenge, generated by Professors Thomas Magnanti and Stephen Graves with LFM staff assistance, was accepted this past year. MIT is now working on the challenge together with IBM, one of five companies hosting universities through the Challenge program. The Institute's Challenge program, expected during the early phase to involve up to 75 Institute faculty and administrators at all levels, is headed by Magnanti; Professors Graves and John Heywood also serve on the Challenge steering committee. (David Wormley, who was originally on the committee, is now dean at Pennsylvania State University's College of Engineering.)

EDUCATION

Graduates

This past June, 34 LFM fellows graduated; the final thesis is nearing completion for a September 1992 graduation, bringing the total to 87 graduates of the Leaders Fellows Program. By June 1992, of the 34 fellows graduating that spring who had confirmed their future plans, 76 percent had taken positions in Leaders partner companies (including the companies that joined the LFM partnership in 1992) and 15 percent had joined other manufacturing companies, choosing from an average of 3.2 job offers. One student entered a PhD program, another opted for part-time work to accommodate new motherhood, and a third accepted a position in a consulting firm.

Examples of LFM Fellows Program graduates' effectiveness on the job include the following:

- Timothy Loucks '90 is superintendent of International Paper's finishing operation in Ticonderoga, NY, responsible for scheduling and distribution as well as production. He supervises twenty-five salaried employees along with 175 hourly workers on three shifts in operations, production, and maintenance. In his two years with International Paper, Loucks has been instrumental in consolidating two facilities into one, relocating over a million pounds of finished goods inventory without missing a single shipping day.

- Jackson Chao '91, reporting directly to Boeing's vice president of operations, 777 Division, is working in a team that is implementing a strategic initiative to reduce both inventory in the Commercial Airplane Group and the 777's manufacturing cycle time. Their program is the first in Boeing's Commercial Airplanes Group to integrate inventory holding cost into the overall cost structure as a tangible measure; the efforts of Chao and associated managers have reduced program lot sizes in some areas by as much as 80 percent.

- Scott Roodvoets '91 supervises tubing production at an Alcoa tube mill in Lafayette, IN, as one of two production managers reporting to the plant manager, overseeing five first-line supervisors and seventy union employees. Since June 1991, the plant manager, the other production manager, and he have improved by 40 percent the plant's promised performance (number of orders shipped during the week scheduled) and raised plant productivity (measured in pounds shipped per employee hour) by 35 percent.

- Ginny Maggs '90 is manufacturing technologies coordinator at Johnson & Johnson's Ortho Diagnostics, reporting to the director of manufacturing. Her responsibilities involve implementing a new manufacturing control system in a 150-worker plant. In 1991, Maggs completed a prototype application of the system for controlling production, automating paperwork flow, and testing and releasing products efficiently. She also served on a multifunctional team that developed a capital funding request, approved this past summer. The team is now carrying the project through development and implementation, probably a three-year project.

Of approximately 70 students supported by the Leaders Program this year in more traditional graduate-degree programs, 14 earned master's degrees and six earned doctoral degrees during the past year.

Students

The Fellows' class size has increased from 20 members in 1988 to 45; this year, 18 percent of the applicants were accepted. Those admitted in 1992 (the Class of 1994) bring an average of 3.8 years of full-time work experience with them, the range extending to 9.5 years. Forty percent of the Class of '94 have work experience in the LFM partner companies; 27 percent of the class are company-sponsored, as sponsored students have proven so effective both in sharing with the partner companies the knowledge generated within the Institute and in increasing the companies' rate of learning about careers and organizational change. The Leaders Program actively seeks women and underrepresented minority students, who comprise almost one quarter of the Fellows Class of 1994.

This past year, Jamie Bonini '92 received the Society of Manufacturing Engineers' Outstanding Young Manufacturing Engineer Award. Miles Arnone, Chad Clawson, and Dan Berkery in the Class of '93 won the $10K Entrepreneurial Competition sponsored by the MIT Entrepreneurs Club and the Sloan New Ventures Association with support from the Sloan School and the School of Engineering.

Curricula

A "manufacturing engineering core" that codifies basic manufacturing principles from an engineering standpoint is evolving from the participating engineering departments' diverse requirements, emphasizing engineering strength in manufacturing and related disciplines. Increasingly popular among the LFM fellows, the core includes a processes course (e.g., 3.52J Materials Processing, 2.810 Fundamentals of Manufacturing Processes), the multidisciplinary 2.739J Product Design & Manufacturing course, the two summer courses of 2.851J Systems Optimization & Analysis for Manufacturing and 3.81J Engineering Probability & Statistics, and two departmental electives. An Alfred P. Sloan Foundation grant helps fund the core development.

This past year, 15.515 Financial & Managerial Accounting was introduced to the LFM Fellows Program summer curriculum. The 2.739J Product Design & Manufacturing and 2.810 Fundamentals of Manufacturing Processes courses were further modified (both supported by the Sloan Foundation to better meet LFM needs). The 15.810 Introduction to Marketing course that the fellows take with other Sloan students was also changed to emphasize quality function deployment, and 3.81J Engineering Probability and Statistics was modified to emphasize applications to quality control and process improvement. The 3.52J Materials Processing course attracted significant numbers of LFM fellows for the first time this past year.

Faculty

Currently the Leaders Program closely involves 50 faculty drawn from many disciplines and functions, actively encouraging them to work across traditional disciplinary boundaries. The program encourages and supports 34 engineering and twenty-one management faculty to visit partner firms. Fifteen faculty serve as "coordinating liaisons" with partner companies, becoming well versed in their company's organization, culture, products, technologies, challenges, and needs in order to facilitate closer working relationships with the Leaders Program. The partner companies have also selected 12 faculty "research liaisons" with whom they are now conducting cooperative research relating to their own specific interests; the Leaders Program has been searching for a Research Program director to coordinate the research activities.

Four junior faculty and one senior faculty who have been involved with the Leaders Program were promoted this year, and tenure was granted another two junior faculty.

Awards to LFM faculty have included H. Kent Bowen's (MSE, EECS) election to Fellow of the American Academy of the Arts and Sciences and the Gordon Y. Billard Award to Thomas Magnanti (Operations Research). Thomas W. Eagar (MSE) delivered the American Welding Society's Comfort A. Adams Lecture at its annual convention, the highest scientific honor bestowed by the society. George Stephanopoulos (ChE) was selected MIT's next Arthur Dehon Little Professor. Dimitris Bertsimas (Operations Research) and Jesús del Alamo (EECS) received Presidential Young Investigator Awards from the National Science Foundation. In memory of her late husband, Anne Bowers Noyce recently established Robert N. Noyce Career Development Professorships in the School of Engineering and the School of Management, awarded this past year to Assistant Professor Mark Jakiela (ME) and Assistant Professor Rebecca Henderson (Corporate Strategy), who have been active in the Leaders Program.

RESEARCH

The LFM Research Program, which is discovering and plans to codify what must be known to teach manufacturing leadership, has been co-directed by Professors Warren Seering and Roy Welsch for the past year. The program links MIT's basic research interests with problems grounded in industry needs, emphasizing teamwork across organizational boundaries and traditional disciplines. Currently, the Research Program funds 34 projects, involving 70 graduate research assistants.

The Leaders Program's list of working papers now includes almost 250 documents, including 88 preprints, 48 published papers, 87 LFM fellows' theses, 19 other SM theses, and two PhD theses covering a wide range of research topics.

During 1991–92, a member of the LFM research staff, Ashraf Alkhairy (whose doctoral work the Leaders partnership partially supported), worked closely with the partner companies to test his method for optimizing product and manufacturing process parameters. Several projects empirically support Alkhairy's theoretical work, indicating his method to be broadly applicable, statistically rigorous, robust against false conclusions — and very efficient. One (Chip MacDonald '92) required 16 experiments using the Alkhairy method compared to 64 using the Taguchi method. MacDonald's recommendations have been implemented, improving product strength 30 percent, thereby saving the partner company $300,000 per year; they have also doubled production capacity, saving an additional $500,000 in capital investment; and they have enabled the company to broaden its product line and resolve critical issues related to vertical integration. A second project (John Glancy '92) required eight experiments using the Alkhairy method, 44 by the Taguchi method, and 75 by the multiple response surface method (MRSM). Glancy's recommendations have allowed a 30 percent product improvement, and tripled capacity.

Paradigm Shifts

At a June 1992 LFM research retreat that strove to break participants' existing paradigms to clear paths for new and more powerful paradigms, faculty and partner company participants began considering a new vision for the program's transitional phase to self-sustainability; they also expanded the concept of *technology transfer from* university *to* industry, to a broader vision for *multidimensional sharing among* partners, and advocated major research initiatives' using measurements to track the progress of organizational and technological change.

Meetings

In October 1991, the program hosted a "workshop symposium" at MIT to tap the insight and experience of partner company practitioners. The interest generated among the 400 attendees was so strong that several subgroups formed during the symposium are still meeting. More symposia have been planned.

The Leaders Program assisted with (and co-sponsored with Stanford University and the Sloan Foundation) the 1992 Operations Management Workshop, bringing together faculty from many leading business and engineering schools and several leading practitioners from industry. In addition to allotting two days to recent research in operations management, the workshop devoted two days to curriculum and career development in design and manufacturing.

COLLABORATIONS

Emerging Institute groups with which the Leaders Program coordinates activities include the MIT Industries Project (launched last spring under the direction of Professor Richard Lester and sharing office space with LFM), the Manufacturing Institute (being developed by Professor Nam Suh), the Organizational Learning Center (directed by Senior Lecturer Peter Senge), the Program on the Pharmaceutical Industry (directed by Thomas Allen, Gordon Y. Billard Professor of Management, and Professor Charles Cooney), the Global Processing Equipment Industries Program (headed by Professors Charles Fine and Thomas Eagar), and the Decision Sciences Program (headed by Professor Thomas Magnanti).

JOHN B. HEYWOOD
THOMAS L. MAGNANTI

Materials Processing Center

INTRODUCTION

Materials synthesis and processing is currently an area of intense national interest, having been identified as a strategic technology area critical to the international competitiveness of several key industrial sectors, including ground and air transportation, electronics, communications, computers, and energy conversion. This conclusion was quantified by a National Research Council study entitled "Materials Science and Engineering for the 1990s—Maintaining Competitiveness in the Age of Materials." Prof. Merton Flemings of MIT and Dr. Praveen Chaudhari, an alumnus of MIT currently at IBM, were the co-chairmen of this important study, which included the input of a large number of MIT faculty. As the premier center of materials processing research in the United States, the Materials Processing Center (MPC) at MIT is in a unique position to take advantage of this new national initiative in materials synthesis and processing.

RESEARCH INITIATIVES

During the past year, the MPC has redefined its role as a catalyst in developing multi-investigator, multidisciplinary materials research programs. A key feature of each of the current and pending programs described below is the interdisciplinary interaction of various faculty and research staff teams. 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, Aeronautics and Astronautics, and Chemistry. The programs described below, all of which were initiated within the past year, illustrate key technologies identified by the MPC as important new areas of research thrust.

Solid Oxide Fuel Cells: Profs. Harry Tuller, Stuart Brown, and Uday Pal of the Dept. of Materials Science and Engineering have initiated a novel program to develop lower temperature solid oxide fuel cell materials as well as processing techniques for these materials. With the international emphasis on reducing emissions from energy conversion, this technology has attracted the attention of several industrial sectors, including the utilities, gas producers, and power equipment suppliers.

Nanosize Semiconductor Particles: Profs. Kirk Kolenbrander and Lionel Kimerling of the Dept. of Materials Science and Engineering have established a core program of study in photonics. Together with Prof. Klavs Jensen of the Dept. of Chemical Engineering and Prof. Moungi Bawendi of the Dept. of Chemistry, they have focused their efforts on the establishment of a research program to develop a process for the production of nanosize semiconductor particles that would be incorporated into a matrix material to form non-linear optical materials and devices. A second project in nanosize semiconductor particles has been initiated by Prof. Michael Cima of the Dept. of Materials Science and Engineering, Prof. Alan Hatton of the Dept. of Chemical Engineering and Prof. Moungi Bawendi of the Dept. of Chemistry. The latter program has recently received funding from the National Science Foundation.

Materials Processing in Magnetic Fields: A wide-ranging proposal to study the effects of solid- and liquid-phase materials processing in magnetic fields was submitted to the National Science Foundation in November 1991. This proposal involved twelve members of faculty and research staff from the Depts. of Materials Science and Engineering, Physics, Electrical Engineering, and the Francis Bitter National Magnet Laboratory.

Institute for Mechanics and Materials: The MPC has teamed with Brown University, Harvard University, and the University of California at Santa Barbara to submit a proposal to the National Science Foundation to establish an Institute for Mechanics and Materials at Brown, with MIT as an active partner. This national Institute will foster education and define research agendas at the interface between the traditional disciplines of solid mechanics and materials science, and provide a focal point for debate and leadership on issues relevant to this research area.

Functionally Graded Materials: The MPC has coordinated a response to an Air Force University Research Initiative with a proposal to study graded interconnected composite structures for high-temperature applications. This innovative program, lead by Prof. Andreas Mortensen, combines parallel, multidisciplinary investigations of the design, fabrication, and evaluation of these materials, and involves a team of ten faculty members from the Depts. of Materials Science and Engineering, Aeronautics and Astronautics, and Chemistry.

The Steel Industry and Industrial Ecology: In response to international concerns about environmental issues, the MPC has initiated a series of discussions on the topic of industrial ecology, which have in turn

led to a potential collaboration with the US steel industry. After several meetings with steel industry leaders and the American Iron and Steel Institute Waste Recycle Technology Task Force, we have identified several areas of mutual interest, ranging from a rational basis for risk assessment to next generation steelmaking technology. In cooperation with the steel industry and lead government agencies, the MPC has agreed to host and co-sponsor a workshop at MIT in early 1993 to focus current efforts and establish short- and long-term research priorities. This initiative is being developed jointly between the MPC and MIT's newly formed PEEER initiative.

Processing Equipment: Prof. Thomas Eagar of the Dept. of Materials Science and Engineering, Prof. Charles Fine of the Sloan School of Management, and Prof. Paul Krugman of the Dept. of Economics have received initial funding for a research program aimed at evaluating the necessity for and requirements of a national focus on the production of processing equipment. This program will study whether or not a nation is at a strategic disadvantage if it must purchase industrial processing equipment from abroad. This program is being developed with partial support from the Leaders for Manufacturing Program and The Industrial Performance Center. As the program grows, it is anticipated that additional MPC faculty will become involved.

An ERC for Materials and Manufacturing: Given the national priority currently assigned to materials and manufacturing, an NSF ERC solicitation in this area is anticipated. The MPC has already focused the attention of its faculty on this initiative and is working directly with the Laboratory for Manufacturing and Productivity to craft a collaborative response.

SYMPOSIA

As part of its mission to disseminate research results and work collaboratively with industry, the MPC sponsors and co-sponsors a number of symposia each year. In the Spring of 1992, the MPC held two successful symposia. The first, which was co-sponsored with the Laboratory for Manufacturing and Productivity and the Leaders For Manufacturing Program, was titled "Prototyping: Rapid Paths to Market" and highlighted the role of prototyping in increasing industrial competitiveness. The day-long symposium featured speakers from both academia and industry and focused international attention on MIT as a leader in this area.

The second symposium held this spring was the fifth in a series of seminars held with Hitachi, Ltd., of Japan. In this seminar, several of Hitachi's top researchers came to MIT to report on their latest results in several important materials and processing research areas. The Hitachi/MIT Seminar series is designed to encourage international cooperation in the dissemination and transfer of research results, in this case with MIT as the forum for access to state-of-the-art research results from Japan. It is intended that similar seminars will be hosted at MIT with other off-shore research-intensive corporations. In this way, we hope to show that MIT fosters an international scientific exchange in all directions.

A third MPC-sponsored symposium, which takes place in July 1992, is titled "Electronics Packaging Research at MIT." This day-long symposium will report on the spectrum of electronics packaging research at MIT as well as highlight the progress of the Electronics Packaging Program, an industrially sponsored, multidisciplinary research initiative begun two years ago and focused on the materials issues affecting the manufacture and reliability of advanced multichip modules.

As part of our ongoing effort to collaborate with industry and the national laboratories, the MPC has joined with the American Welding Society and DOD's Naval Surface Warfare Center to organize a September 1992 conference in Cambridge , Massachusetts, on High Energy Electron Bean Welding and Materials Processing. The goal of this conference is to discuss and identify potential commercial applications for this technology, which was originally developed as part of the US Defense Department's particle beam weapons system. In this way, we hope to produce an example of "turning swords into plowshares."

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 publications 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.

Materials Processing and Manufacturing Institute

The MPC has recently proposed the Materials Processing and Manufacturing (MP&M) Institute, a program which would provide graduate materials processing and engineering education on a cooperative basis between MIT facilities and industrial sites. The plan calls for groups of MIT faculty to work closely with industrial partners to select long-range problems, after which teams of MIT faculty and students will work to develop potential solutions through research projects performed at MIT. As these solutions develop, the teams will work with the companies to implement the technology in the industrial environment, in many cases requiring the students to complete a portion of their work at industrial sites. The goal of the MP&M Institute is to generate closer interaction between scientific developments at MIT and the technological needs of industry by integrating engineering education and commercial process development. The MPC Industrial Advisory Board, which met in February 1992 to discuss the Center's activities and future plans, was enthusiastic about the MP&M Institute and felt that the program deserved our highest priority. We are currently working to secure industrial endowment for this program.

Summer Scholar Award Program

The MPC is now in its ninth year of the Summer Scholars Program, which is funded through our Industry Collegium. This program brings outstanding non-MIT undergraduates to MIT to participate in a ten-week summer research project in materials processing. The scholars are generally non-materials science majors, which is part of the Program's overall goal of attracting a multidisciplinary array of students to graduate study at MIT. In fact, a third of all MPC Summer Scholars from past years have returned to MIT for graduate study.

ALLOCATION OF RESOURCES

The MPC has the distinct advantage of having the strongest and most successful industrial collegium at MIT. This is a source of significant financial resources, which we use to strengthen not only the programs of the MPC, but to strengthen the entire materials processing community at MIT. Our joint symposia and research proposals with other MIT Centers and Laboratories are funded entirely from MPC funds. In addition, we have used a major portion of our resources to reduce our outstanding debt from prior operations by more than 75 percent during the past year. We fully expect to complete this debt retirement before the end of this calendar year.

During the past year we have shifted the major focus of our resource allocations from graduate fellowships to unrestricted grants for recently hired junior faculty. We feel this will provide a longer term investment in the future strength of MIT.

AFFIRMATIVE ACTION

The MPC has no faculty on its rank list. In our hiring of staff we make every effort to locate qualified minorities or women, in full compliance with MIT's affirmative action policies.

CONCLUSIONS

As we begin our second decade at the MPC, we are gratified to report that the Center is stronger and more vital than ever. Our outstanding debt left over from prior Center operations has been reduced markedly. In addition, we have maintained our level of funding despite the current difficult economic times; moreover, we anticipate increasing our industrial sponsorship when the national economy rebounds. Indeed, in this era of sharply decreased defense spending, sponsorship for research into advanced materials and processing will increasingly come from non-governmental sources. We feel that the groundwork the MPC has already laid in establishing relationships with industry will be instrumental in our effort to bring industry more fully into the academic research environment.

T.W. EAGAR

Program in Environmental Engineering Education and Research

INTRODUCTION: Technology for a Sustainable Environment
There is a considerable amount of environmental education and research activity at MIT covering the vast range of topics from waste management and environmental remediation to waste minimization and environmental policy studies. These interdisciplinary activities, however, have been diffused throughout the institute's structure with little cohesion and critical mass. On January 1, 1992, the Program for Environmental Engineering Education and Research (PEEER) was formed to address the need for synergy and momentum. The undertaking grows out of the five-year grass roots efforts of the MIT Hazardous Substances Management Program to grow such coordination. The program which reports to the Dean of the School of Engineering is designed to explore the relationship between technology and a sustainable environment and draws on the extensive environmental resources and interests in each of MIT's five Schools. PEEER will enhance not only environmental education ongoing within MIT departments but will also seek to influence the education of all professionals in this important area. New research will complement the educational focus of the program. Both will cross and reform disciplinary lines reflecting the systems' context of individual technologies in the identification of research needs and methods of implementation. Through a carefully structured process of interdisciplinary communication the program will, in effect, create a new paradigm for environmental education and research in four areas; (1) waste minimization, pollution prevention, clean technologies, recycling and industrial ecology; (2) modeling environmental sustainability; (3) waste management and environmental remediation, and (4) better integration of science and technology into environmental policy analysis.

Developments in each of these areas are necessary to complete the entire program because the "cradle-to-grave" management of processes and materials that may alter the environment requires a contextual view of each potential impact. Each context includes interlocking natural, technological and political aspects. Environmental Educational activities now under consideration are: 1) an environmental minor for all majors in all five Schools at MIT, 2) environmental literacy subjects and lectures for all majors at the undergraduate and graduate levels, 3) incorporation of environmental concerns into the professional subjects of all majors, 4) developing new curriculum materials for environmental subjects at MIT and other institutions, 6) continuing education and lifelong learning for practicing professionals, and 7) promotion of new subjects in clean technologies, source control and industrial ecology.

The Hazardous Substances Management Program, the predecessor to PEEER has developed and supports a four subject sequence entitled Chemicals in the Environment which is designed to give graduate and undergraduate students the skills they will need to become effective managers of hazardous substances. The subjects have been developed to provide a systematic and interdisciplinary look at the critical issues of chemicals introduced into the environment and work place. They are taught by senior faculty associated with PEEER. These subjects are: 10.72 Sources and Control, Chemical Engineering, 1.725 Environmental Fate and Transport, 1.04 Chemicals and Human Disease, and 11.363 Policy and Management. These subjects each attract thirty-five students per year and the sequence won the 1991 MIT Sizer Award for Educational Innovation.

The Structure of the PEEER Organization
PEEER is an example of a new experiment in the School of Engineering on "virtual organizations" which do not operate as formal structures such as laboratories, centers or departments. Rather they represent the voluntary interaction of institute faculty, staff and students who are drawn by the intellectual challenge of the new area. They help to organize the intellectual themes and work across disciplinary boundaries to make things happen while remaining members of their

departments. Primary participants in the PEEER program are such volunteers. The PEEER Steering Committee includes:
David H. Marks, Professor of Civil and Environmental Engineering, Director, PEEER, environmental systems and management; John Ehrenfeld, Senior Lecturer in Chemical and Civil Engineering and Director of the Program in Technology, Business and the Environment, CTPID, industrial ecology; Francois Morel, Professor of Civil and Environmental Engineering and Head of the Parsons Laboratory for Water Resources and the Environment, fate and transport of heavy metals in the environment; Daniel Roos, Professor of Civil and Environmental Engineering, Director of the Center for Technology Policy and Industrial Development, technology and policy; Donald Sadoway, Professor of Materials Science and Engineering, clean technologies; Adel Sarofim, Du Pont Professor of Chemical Engineering, incineration and air borne toxics; Lawrence Susskind, Professor of Urban Studies and Planning, environmental negotiation; Jefferson Tester, Professor of Chemical Engineering and Head of the MIT Energy Laboratory, clean technologies, and William Thilly, Professor in the Division of Toxicology, Whitaker College, and Head of the Center for Environmental Health Sciences, pollution and human health.

Other participants during the Academic Year 1991-92 are: David Bernstein, Assistant Professor of Civil and Environmental Engineering, transportation and the environment; Nazli Choucri, Professor of Political Science, global environmental policy; Joel Clark, Professor of Material Science and Engineering, materials systems laboratory, automobile recycling, materials and manufacturing processes; Ahmed Ghoniem, Professor of Mechanical Engineering, air pollution modeling; Michael Golay, Professor of Nuclear Engineering, waste remediation and minimization, Philip Gschwend, Associate Professor of Civil and Environmental Engineering, fate of chemicals in the environment; Kent Hansen, Professor of Nuclear Engineering, waste remediation and minimization; Harold Hemond, Professor of Civil and Environmental Engineering, acid rain, wetlands, fate and transport of chemicals in the environment; Patricia Hynes, Lecturer, Department of Urban Studies and Planning, environmental policy; Judith Kildow, Associate Professor of Ocean Engineering, environmental policy; Leslie Norford, Assistant Professor of Architecture, indoor environmental quality; Dennis McLaughlin, Associate Professor of Civil and Environmental Engineering, groundwater pollution; Gregory McRae, Professor of Chemical Engineering, air pollution modeling and management; Fred Moavenzadeh, George Macomber Professor of Civil and Environmental Engineering and Director, Center for Construction Research and Education, construction and the environment; Ronald Probstein, Ford Professor of Engineering, Mechanical Engineering, clean technologies; Philip Gschwend, Associate Professor of Civil and Environmental Engineering, fate of chemicals in the environment; Julian Szekely, Professor of Materials Science and Engineering, clean technologies; Ian Waitz, Assistant Professor of Aeronautics and Astronautics, environmental impacts of air transport.

Reporting on the Richness of MIT Environmental Activities: The *Environment MIT* newsletter

One of the first activities initiated by PEEER is a newsletter, *Environment MIT* with Dr. Teresa Hill as editor. The objective of this activity is to familiarize interested parties with the range of environmentally related work ongoing throughout the institute. The newsletter, which appears about every six weeks, was designed to "provide a forum for discussion...of directions for environmental education and research at MIT," a discussion in which voices from many disciplines needed to be heard. A summary is presented here of the first year's major topics which give a brief glimpse at the richness and depth of environmental activities at MIT.

Within the first two issues, a roundup of the major research programs was presented; subsequent issues publicized new programs as they emerged. Notable examples are the Provost's Council on the Global Environment, and the Joint Program on the Science and Policy of Global Change. Reports on new research projects brought together such diverse topics as the disposal of hazardous wastes

through pyrolysis (Plasma Fusion Center); the environmental microbiology of polluted watersheds (Parsons Laboratory); the relationship of energy, environment and transportation policies in China (Special Program for Urban and Regional Studies); innovative strategies for corporate environmental management (Technology, Business and the Environment Program); and the project to design spill-resistant oil tankers (Department of Ocean Engineering). The newsletter also announced the formation of the EPA "Center of Excellence" in Air Pollution Research at MIT, the awarding of a Mac Arthur Foundation Grant to the Humanities and the Environment group (STS); and, in a special issue, the $3 million gift of the Martin Foundation in support of research and education on global environmental issues. This special issue was used as the Institute News Office's announcement of the Martin award to the press.

Another goal of the newsletter has been to attract participation in meetings on environmental subjects in an effort to promote interdisciplinary perspectives. Each issue has detailed symposia, workshops, seminars, and other types of meetings reflecting the topical and methodological diversity of environmental issues.

A special feature this year has been an ongoing exploration of the meaning of "environmental literacy", a phrase as widely used as it is ill-defined. Five leaders in environmental studies at MIT have contributed their thoughts on how to organize education for environmental professionals and promote environmental awareness among all students. Writers have included Dr. John Ehrenfeld, and Professors Rafael Bras, Lawrence E. Susskind, Henry D. Jacoby, and Leo Marx. This exchange of views has provided a philosophical underpinning for perhaps the most important objective of the newsletter, helping to structure environmental education for the future.

MIT offers a rich array of educational opportunities in environmental studies. In recent years, the number of programs has proliferated. The key objective of PEEER is to "coordinate and build upon the Institute's growing strengths in environmentally oriented educational and research activities". The first two issues of the newsletter brought together for the first time a list of the many programmatic pathways to environmental education at MIT, from several perspectives and levels of professional commitment. At mid-year, a special feature listed all IAP offerings in environmental studies. In the final issue for 1991-92, the editors reported on the initiative to establish an minor for environmental studies in all five schools, as part of the four-level structure of environmental education envisioned by PEEER. The steering committee will continue to use the newsletter to provide a forum for views on the philosophy of environmental education, for the promotion of enrollment in existing programs and courses, and for debate on coordinating future approaches to environmental education for all MIT students.

Five issues of *Environment MIT* were published during the academic year 1991-92. Originally intended for distribution to all faculty members and others involved in environmental studies within the Institute, the newsletter has been used extensively by outreach groups including the Industrial Liaison Program (ILP) and the Provost's Council on the Global Environment. It has been particularly welcomed by resource development officers who have used the publication to promote interest in supporting environmental activities at MIT. The newsletter is also distributed, by request, to a mailing list of 200 people outside MIT, including alumni, faculty and students in environmental programs at other universities, and individuals in public and private sectors. Next year funds will be raised to distribute the newsletter to a much larger internal and external audience.

D.H.Marks

Technology, Management and Policy Program

Technology, Management and Policy Program (TMP) is a new cooperative, interdisciplinary, research and educational program among existing centers, laboratories and academic initiatives. The initial participants include the Center for Technology, Policy and Industrial Development (CTPID), Technology and Policy Program, Materials Systems Laboratory, Program in Environmental Engineering, Education and Research (PEEER), Center for Construction Research and Education, and Center for Transportation Studies.

Focusing on large scale systems, TMP strives to define a new paradigm of engineering education and practice which complements and extends the traditional science-based academic disciplines. Among the Program's key educational goals is the establishment of a coherent interdisciplinary doctoral program in Technology, Management and Policy. An important objective of the Program is to achieve broad-based participation from all of the departments within the School of Engineering and to facilitate closer academic relationships with other schools within MIT.

TMP is motivated by the need to find new approaches for understanding and managing technological change, recognizing the increasing scale, complexity and rate of change characterizing many systems and processes driven by scientific and technological factors. Some examples include whole industries, transportation networks, communications systems, and the global environment. These systems are large and complex from technical, organizational, institutional and social perspectives, involving many interacting components and stakeholders. They often transcend national boundaries, may present downside risks which are imperfectly understood, and may have large, widespread and long-lasting impacts entailing vexing mitigation issues. In some cases the negative consequences of these systems or processes, such as global warming, may become evident after many decades and may take equally long to reverse.

In light of the mounting challenges posed by the emergence and pervasiveness of large scale systems and processes, a primary goal of the Program is to increase basic knowledge through research focusing on specific large scale systems problems that provide insight into, and understanding of, the characteristics and behavior of these systems. This includes research on the dynamics of adaptation and change in specific industries, environmental sustainability, management of specific large scale systems (e.g., intelligent vehicle highway systems), and process studies focusing on how organizations work together (e.g., stressing private-private, public-public, public-private relationships). Also important is the development of general frameworks, methodologies and procedures that can be used in the planning, design and operation of large scale systems, through both problem-oriented studies and parallel basic research efforts.

TMP further aims at creating enhanced educational opportunities for students in the existing degree programs offered by the participating centers, laboratories and activities, developing an interdisciplinary doctoral program, and providing better coordination of continuing educational programs for practicing professionals. A related goal of the Program is to develop educational subjects that explore the issues and challenges of large scale systems for all students in the School of Engineering, in the belief that engineering students, both undergraduate and graduate, would benefit from developing a better understanding of how engineering practice embraces a broader set of considerations falling beyond traditional technical disciplinary boundaries.

DANIEL ROOS

SCHOOL OF HUMANITIES AND SOCIAL SCIENCE

This year the School of Humanities and Social Science (SHSS) continued to focus its efforts on fund-raising, curriculum reform, affirmative action, and faculty recruitment in departments and sections which are experiencing a significant number of retirements and resignations. The faculty within the School received a number of honors and awards, and some important administrative changes within the School have occurred.

Undergraduate Education

The Class of 1992 was the first to have entered under the Humanities, Arts, and Social Science-Distribution (HASS-D) system. For that reason, and in response to a request from the Academic Council, data is being collected and compiled on the Class of '92 for a "HASS-D Output Analysis." This project includes compiling statistics and summarizing interviews concerning the HASS Requirement with a sample of this year's graduating class.

The Academic Council's request was a response to the "Interim Report on the HASS-Distribution Requirement", which it discussed last fall. The Report was the result of the three-year interim review of the HASS-D system which had been conducted by the HASS-D Overview Committee during AY 1990-91. Besides the Academic Council, it was discussed by several other groups, including the SHSS Council, the Committee on the Undergraduate Program (CUP), and the Committee on Curricula (COC). In general, the Overview Committee felt that the system has been successful, and recommended no major changes at this time. Several slight modifications were recommended and approved, including a reduction in the minimum number of pages of required writing from 25 to 20; licensing HASS-D subjects normally for three years (instead of granting one-year licenses to some and three-year licenses to others); and removing the first preference for seniors from the lottery system. A recommended change that would permit HASS-D instructors to administer take-home final exams instead of scheduled exams has been approved by CUP on an experimental basis for a three-year period. Although the Overview Committee discussed several options for a more basic change to the distribution system itself, it is not recommending a change at this time. A more thorough review will be conducted in two years, after the system has been in effect for six years.

There will be 77 HASS-D subjects offered in 1992-93, which represents an increase from the 74 offered in 1991-92. Since this is just above the target number of 75, the goal for the future will be to keep the number of subjects stable, although some subjects will be phased out and new ones added.

The HASS Minor Program, an intermediate option between the HASS concentration of three or four subjects in a given field and the HASS major, continued to grow, as it has each year since it was introduced. At the end of 1991-92, 497 students were registered as candidates for a Minor, compared with 443 students in 1990-91. Six new Regional Studies Minors were approved to go into effect in 1992-93: African and African Diaspora Studies, East Asian Studies, European Studies, Latin American Studies, Middle Eastern Studies, and Russian Studies. This increases the number of HASS Minors from 19 to 25.

As a result of an MIT faculty vote in spring 1989, June 1992 Course XXI majors were the third class to graduate with degrees that designate their specific fields. Thirty students receiving Course XXI degrees in February and June 1992, including 12 who completed joint degrees with science or engineering. The total number of undergraduate majors in the School decreased this year, due mainly to the reduction of majors in Economics (115 in 1990-91 down to 81 in 1991-92), and Political Science (44 in 1990-91 down to 35 in 1991-92).

New Initiatives

In its second year, the Cultural Studies Project expanded the range of its interdisciplinary activities. It sponsored two national conferences ("Pomp and Circumstance: Political Uses of Public Culture" and "Shakespeare: Film/Performance/Hypermedia") as well as faculty working groups such as the Biographers' Roundtable. It initiated a series of Visiting Scholars, including Robert Darnton of Princeton University, Joan Scott of the Institute for

Advanced Study, and Mary Louise Pratt of Stanford University, each of whom came for several days of intensive interaction with faculty and students. Also new this year was *Civitas*, the cultural studies newsletter. The project has been supported with funds from the Provost and the Dean and is directed by Professor David Thorburn of the Literature Faculty; faculty from throughout the humanities and arts participate in its programs.

Foreign Languages and Literatures, with the assistance of a grant from the Chiang Ching-kuo Foundation, continues to expand their East Asian component with the establishment of a Chinese Language, Literature and Culture Program. Coordinated by Visiting Assistant Professor Yih-jian Tai, an expert on Classical Chinese Drama, the program offered Beginning Chinese as well as Chinese Literature in translation in 1991-92. In 1992-93, Intermediate Chinese will be added to the curriculum.

In June 1992, MIT and the Dibner Fund signed a ten-year (renewable) Affiliation Agreement that establishes at MIT the Dibner Institute for the History of Science and Technology and the Burndy Library. The Dibner Institute is an independent consortium of MIT, Harvard, Brandeis, and Boston University that is devoted to research in the history of science and technology. The first Director of the Dibner Institute will be Professor Jed Buchwald, formerly of the University of Toronto. He will also hold the first of two professorial chairs that the Dibner Fund has established at MIT in the history of science and technology. His faculty appointment will be in STS and the History Faculty. In addition to the two Dibner Chairs, the Dibner Fund has provided the resources to support four graduate fellowships for students in the MIT doctoral program in the History and Social Study of Science and Technology. The chairs and fellowships constitute one of the largest single donations ever made to the Humanities at MIT. The Dibner Institute will annually sponsor and house at 38 Memorial Drive (Building E56) ten senior scholars and post-doctoral fellows in the history of science and technology fields. The combination of the MIT doctoral program and the Dibner Institute, with the MIT Library collection in the history of science and technology and the Burndy Library collection, will make MIT a world center for the study of the history of science and technology.

Affirmative Action

The affirmative action record of SHSS 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 21 are tenured (18 percent of the tenured faculty). Over the past five years, the total number of women faculty has remained essentially constant. However, we were successful this year (owing to the Provost's new program to attract women and minorities to MIT) in recruiting three women to the faculty next year (two in STS and one in Music and Theater Arts). This will bring the number of women faculty members to 35 next year.

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 (underrepresented) minority faculty members and two untenured (underrepresented) minority faculty members within the School. In 1991-92, four offers were made to members of underrepresented minorities; two in Political Science, one in Economics, and one in the Program in Science, Technology, and Society (STS). The STS offer has been accepted and the number of untenured underrepresented minorities will have increased by one. The School's record with respect to underrepresented minority administrative staff members is somewhat better, with three underrepresented minorities of a total of 23 (13%). The School remains committed to increasing the number of minority faculty and administrative staff members. To this end, the departments and sections within the School may not go forward with search plans without the determination of the relevant pool of minority appointments. Moreover, the Dean has encouraged certain departments and sections to make appointments in fields in which significant numbers of underrepresented minorities are known to be involved.

Honors and Awards

The faculty within the School of Humanities and Social Science garnered an impressive array of honors and awards this year. The most notable among them were the following: Professor John Harbison of the Music and Theater

Arts section was awarded membership to the Institute of Arts and Letters. In addition Music's Evan Ziporyn (Assistant Professor) received the Institute's Wade Award and has been selected to be the next holder of the Class of 1958 Career Development Professorship in recognition of innovative and imaginative teaching. Professors George S. Boolos and Robert Stalnaker of the Department of Linguistics and Philosophy and Professor Paul R. Krugman of the Department of Economics were elected Fellows of the American Academy of Arts and Sciences. Professor Willard Johnson of the Department of Political Science was named an African-American Man of Vision by the Museum of African-American History in Boston. Professor Haywood Alker of Political Science serves as President of the International Studies Association and President of the Institute for Defense and Disarmament Studies, as well as on the Executive Committee of the International Social Sciences Association. The Department of Linguistics and Philosophy's Professor Judith Thomson was named Laurance S. Rockefeller Professor of Philosophy; and Associate Professor Irene Heim the Class of 1943 Career Development Professor. Assistant Professor Janet Currie of the Department of Economics has been selected to be an NBER Olin Fellow; and Professor Peter Diamond was named as the first Paul A. Samuelson Professor of Economics. Professor Catherine Chvany of the Foreign Languages and Literatures section received the Distinguished Career Achievement Award for Outstanding Contributions to Scholarship at the 50th Anniversary celebration of the American Association of Teachers of Slavic and East European Languages. Assistant Professor Douglas Forsyth of the History faculty received the Class of 1942 Career Development Chair; and Professor Peter Perdue received the Levitan Prize in the Humanities for his project on the expansion of the eighteenth-century Chinese empire into Central Asia. Professor Rudiger Dornbusch of the Department of Economics was awarded the Harms Prize from the Institute for World Economics at the University of Kiel, Germany; and Professor Stanley Fischer was appointed as Elizabeth and James Killian Professor, as well as Honorary Professor in Universidad del Pacifico, Lima, Peru. Assistant Professor Henry Jenkins III of the Literature section was awarded the Harold E. Edgerton Award in recognition of distinguished teaching, research and service to the MIT community. Honorary degrees were awarded to Professors Noam Chomsky (Gettysburg College and the University of Maine) and Morris Halle (University of Chicago) of the Department of Linguistics and Philosophy, and to Professor Robert Solow of the Department of Economics from SUNY, Albany and Harvard University. Professors Emeriti Walter A. Rosenblith and Leo Marx of the Program in Science, Technology and Society were awarded honorary degrees by the University of Miami and Colby College.

Fundraising

As MIT's *Campaign for the Future* entered its fifth and final year, the School continued its efforts to raise funds from foundations, corporation and individual donors. Foundations were a major source of support. The Program in Science, Technology and Society (STS) received a $500,000 grant from the MacArthur Foundation for a multidisciplinary study of the relation of human societies to the environment. STS also received a $1.5 million grant from the Sloan Foundation for the development of a textbook on the history of American technology. The World Economy Laboratory, a new research center within the Department of Economics, was given a grant of $352,755 from the Ford Foundation for a project on "From Stabilization to Growth," a study of the economies of Peru and Brazil. The first payment of $1 million of a $5 million grant from the Knight Foundation was received by the Knight Science Journalism Program after a match of $282,000 was provided by MIT.

The US-Japan Program, a part of the Center for International Studies, continues to be the main recipient of corporate funding, with modest support coming from IBM, Ford Motor Company, Digital, and other major American corporations. The World Economy Laboratory also received contributions from GTE and the Institute of Mitsui. This last resulted from intense fundraising efforts in Japan on the part of the Economics faculty over the past two years. The positive benefit of this activity is expected to be seen over the next several years.

Efforts to raise funds from individuals met with success during FY92. Pledges and gifts in the $25K and $50K range continued to be received from the School's relatively small pool of alumni. Two large gifts came from alumni of other MIT Schools: Harry Kalker 23CE -- pledged $1 million to the Center for International Studies to be paid in yearly installments of $100K over a ten-year period, and Kenneth Fang 62CH -- pledged $1 million to the Chinese language program to be paid in two installments of $500K each. This latter gift resulted from a trip taken to the Far East by the Dean and the Assistant Dean of Development. A follow-up fundraising trip will be undertaken in FY93.

A fundraising trip to Europe is also planned during that period. As part of the 10-year Affiliation Agreement that brings the Dibner Institute and Burndy Library to the MIT campus, the Dibner Fund pledged two professorial chairs in the history of science and technology and four graduate fellowships per annum to the Ph.D. Program in the History and Social Study of Science and Technology.

Two major grants were received from federal agencies. The National Science Foundation awarded the Department of Linguistics and Philosophy a five-year grant of $1.3 million to establish a multidisciplinary program with the Department of Brain and Cognitive Sciences to give selected graduate students intensive research training in language structure, acquisition, and use. The MIT-Japan Program received a $2.6 million grant from the US Air Force for the expansion of its program.

Administrative Changes, Retirements

This year has seen two retirements, five resignations, and eleven new faculty appointments within the School. As of June 30, 1992, Professor Robert Jones of the Foreign Languages and Literatures Section and Professor Lucien Pye of the Department of Political Science will retire. We wish them great success in all their future endeavors as emeriti professors of MIT. The School saw five resignations this year, including three in the Department of Economics (Assistant Professor Danny Quah to the London School of Economics, Assistant Professor Thomas Lemieux to the University of Montreal, and Professor Jean Tirole to the University of Toulouse in France. Professor Tirole will continue his relationship with MIT, however, as a visiting professor for 1992-93.); one in the Department of Linguistics and Philosophy (Assistant Professor Paul Hoffman to the University of California at Riverside); and one in the Program in Writing and Humanistic Studies (Assistant Professor Thomas Simmons to the University of Iowa).

The School was successful in recruiting eleven new members to the faculty for 1992-93. They include three in the Department of Economics (Assistant Professors Jushan Bai and Jonathan Gruber, and Associate Professor without Tenure Ricardo Caballero); three in the Program in Science, Technology and Society (Professors Jed Zachary Buchwald - joint with History Faculty - and Evelyn Fox Keller and Assistant Professor Evelyn N. Hammonds); one with a joint appointment in the Anthropology/Archaeology Program and the Program in Science, Technology and Society (Assistant Professor Hugh Gusterson); two in the Foreign Languages and Literatures Section (Assistant Professors Martin Roberts and Bernd Widdig); one in the Department of Political Science (Associate Professor with Tenure James Snyder); and one in the Music and Theater Arts Section (Assistant Professor Janet Sonenberg). In addition, we will welcome Betsey Barker Price as a Senior Lecturer in the Humanities.

Effective July 1, 1992, Professor Kenneth Keniston will step down after five years of service as Director of the Program in Science, Technology and Society, and Professor Merritt Roe Smith will replace him. Professor Suzanne Berger will step down after three years as Head of the Department of Political Science, effective September 1, 1992. She will be replaced by Professor Richard Samuels. Professor Myron Weiner of the Department of Political Science will step down as head of CIS after five years, effective July 1, 1992. He will be replaced by Associate Professor Kenneth Oye of the Department of Political Science. We will miss the insights and administrative wisdom of Professors Berger, Keniston, and Weiner and wish them well as they return to professional lives focused on full-time scholarship and teaching.

PHILIP S. KHOURY

TABLE I
ENROLLMENT IN HUMANITIES, ARTS, AND SOCIAL SCIENCE SUBJECTS: 1991-92

Field	Elective Subjects		HASS-Distribution		Total Enrollments	
	# of Subjects	# of Students	# of Subjects	# of Students	# of Subjects	# of Students
Anthropology/ Archaeology	16	187	5	170	21	357
Economics	18[45]	1446	2	27	20[47]	1473
Foreign Languages & Literature	66[94]	1219	21[36]	476	87[130]	1695
History	39	352	16[18]	463	55[57]	815
History of Art & Architecture	1	16	3	102	4	118
Linguistics	2	38	0	0	2	38
Literature	31	390	25[39]	814	56[70]	1204
Music	21[25]	499	7[13]	421	28[38]	920
Philosophy	25	283	5	229	30	512
Political Science	23	222	8[9]	192	31[32]	414
Psychology	6	103	1	309	7	412
STS	14	99	6	112	20	211
Theater Arts	11[15]	209	6	44	17[21]	253
Urban Studies	6	119	5	111	11	230
Visual Arts	9	69	2[5]	104	11[14]	173
Women's Studies	10	42	4	40	14	82
Writing	36[55]	811	4[8]	178	40[63]	989
TOTALS	334[416]	6104	120[165]	3792	454[581]	9896

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 1992

Fields of Concentration	Class of 1995		Class of 1994		Class of 1993		Class of 1992		Totals in Fields	
American Studies	(0)	0	(3)	0	(2)	0	(8)	8	(13)	8
Ancient & Medieval	(0)	0	(12)	1	(11)	5	(12)	12	(35)	18
Anthropology/Archaeology	(0)	0	(10)	0	(13)	1	(14)	14	(37)	15
Black Studies	(0)	0	(0)	0	(0)	0	(1)	1	(1)	1
East Asian Studies	(0)	0	(0)	0	(2)	0	(4)	2	(6)	2
Economics	(1)	0	(106)	5	(174)	54	(231)	203	(512)	262
Ethnic Studies	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0
Film & Media Studies	(0)	0	(4)	0	(8)	2	(13)	12	(25)	14
Foreign Languages**	(0)	0	(103)	14	(130)	37	(173)	134	(406)	185
History	(0)	0	(16)	1	(26)	6	(65)	56	(107)	63
History of Art	(1)	0	(1)	0	(1)	0	(8)	8	(11)	8
Labor in Industrial Society	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0
Latin American Studies	(0)	0	(0)	0	(1)	0	(1)	0	(2)	0
Linguistics	(0)	0	(5)	0	(2)	0	(5)	4	(12)	4
Literature	(0)	0	(20)	2	(56)	11	(93)	68	(169)	81
Music	(1)	0	(34)	1	(88)	6	(95)	80	(218)	87
Philosophy	(0)	0	(22)	3	(26)	8	(46)	42	(94)	53
Political Science	(1)	0	(17)	1	(27)	6	(58)	52	(103)	59
Psychology	(0)	0	(19)	0	(45)	18	(107)	96	(171)	114
Russian Studies	(0)	0	(0)	0	(4)	2	(11)	9	(15)	11
Science, Technology, & Society	(0)	0	(12)	2	(12)	3	(14)	10	(38)	15
Theater Arts	(0)	0	(11)	1	(16)	8	(19)	18	(46)	27
Urban Studies	(1)	0	(11)	0	(5)	0	(5)	5	(22)	5
Visual Arts & Design	(0)	0	(4)	0	(7)	0	(10)	8	(21)	8
Women's Studies	(0)	0	(3)	0	(9)	0	(10)	10	(22)	10
Writing	(1)	0	(27)	0	(38)	7	(62)	55	(128)	62
Special Concentrations	(2)	0	(3)	0	(6)	3	(10)	9	(21)	12
TOTALS	(8)	0	(443)	31	(709)	177	(1075)	916	(2235)	1124

* 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:

Chinese	(0)	0	(11)	0	(5)	1	(2)	1	(18)	2
ESL	(0)	0	(1)	0	(0)	0	(5)	2	(6)	2
French	(0)	0	(11)	2	(34)	7	(38)	29	(83)	38
German	(0)	0	(30)	2	(26)	10	(27)	22	(83)	34
Japanese	(0)	0	(16)	0	(14)	3	(20)	10	(50)	13
Russian	(0)	0	(8)	4	(18)	7	(17)	16	(43)	27
Spanish	(0)	0	(25)	6	(28)	8	(50)	44	(103)	58
Other Languages	(0)	0	(1)	0	(3)	1	(10)	8	(14)	9
World Literature	(0)	0	(0)	0	(2)	0	(4)	2	(6)	2

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TABLE III

Undergraduate Majors in the School of Humanities and Social Science

Year	Economics	Humanities*	Philosophy	Political Science	Total
1982-83	48	37	7	28	120
1983-84	48	24	3	22	97
1984-85	52	30	2	15	99
1985-86	51	52	5	26	134
1986-87	49	57	7	21	134
1987-88	76	77	9	40	202
1988-89	103	52	11	43	209
1989-90	111	51	13	54	229
1990-91	115	64	13	44	236
1991-92	81	75	12	35	203

*These figures do not include double majors who registered first in a course other than Humanities. (If you include double majors, the figure is 103.)

TABLE IV

Graduate Students in the School of Humanities and Social Science

Year	Economics	Hist & Soc Study of Sci & Tech	Linguistics & Philosophy	Poli Sci	Total
1982-83	136	–	51	163	350
1983-84	113	–	52	99	264
1984-85	108	–	53	121	282
1985-86	130	–	59	171	360
1986-87	105	–	55	115	275
1987-88	120	–	72	157	349
1988-89	127	4	67	118	316
1989-90	132	9	77	154	372
1990-91	134	13	61	154	362
1991-92	139	17	53	160	369

TABLE V
HASS MINOR APPLICATIONS
FOR CLASSES OF 1992, 1993, 1994 AND 1995

FIELD	TOTAL APPLICATIONS
Anthropology/Archaeology	10
Economics	140
Film and Media	14
Foreign Languages	
French	16
German	29
Spanish	20
Russian	7
History	20
History of Art and Architecture	5
Literature	52
Music	72
Philosophy	4
Political Science	30
Psychology	22
*Regional Studies Minor Programs	
African & African Diaspora	0
East Asian Studies	1
European Studies	0
Latin American Studies	0
Middle Eastern Studies	0
Russian Studies	1
Science, Technology, and Society	2
Theater Arts	15
Urban Studies and Planning	4
Women's Studies	5
Writing	28
Total Minor Applications	497

* New Programs: Approved in spring term, AY 1991-92

The HASS Office continued to serve multiple functions, including the administration of the eight-subject HASS requirement, the HASS Minor, the Harvard Cross-Registration Program, provision of statistics for the School of Humanities and Social Science, and the publication of the HASS Guide each term. This office has the responsibility, on behalf of the Registrar's Office, of recording proposal and completion forms for both concentrations and minors on each student's record. Petitions for HASS credit for subjects which are not so coded, such as Harvard and Wellesley subjects, graduate subjects, etc., are submitted here for approval. Information concerning any of the above, as well as HASS transfer credit and general Institute information, was provided to the MIT community and in response to inquiries from outside the Institute. In addition to the above, the Coordinator served as staff to the HASS-D Overview Committee and the HASS Minor Committee, and worked with Leslie Perelman and others from the UAAO on the "HASS-D Output Analysis" project, which includes compiling statistics and summarizing interviews with the Class of 1992 concerning the HASS Requirement.

HASS ENROLLMENT STATISTICS BY FIELD AND SUBJECT - - RECENT TRENDS

The number of HASS subjects offered in 1991-92 increased from 418 to 454, with the number of autonomous sections increasing from 562 to 581. The HUM-D subjects have effectively been phased out, as the Class of 1991 was the last class to have entered under that requirement. The increase in the number of HASS elective subjects (from 280 to 334) is partially the result of that phasing out, since many of the former HUM-D subjects became HASS electives. There was also a slight increase in the number of HASS-D subjects offered (from 108 to 120); the enrollment in HASS-Ds remained approximately the same. The largest overall enrollments were in Foreign Languages and Literatures (1695), followed by Economics (1473) and Literature (1204). Many fields showed growth in enrollments; some of the larger increases (besides the fields just listed) were in Music (from 786 to 1204), Writing (from 720 to 989), and Anthropology/Archaeology (from 257 to 357).

HASS CONCENTRATIONS: PATTERNS OF POPULARITY

Economics was once again the most popular field of Concentration, followed by Foreign Languages and Literatures, Music, Psychology, and Literature. There are 512 proposed concentrations in Economics, 406 in FL&L, and 218 in Music. Psychology and Literature are nearly tied for fourth place, with 171 proposals in Psychology and 169 in Literature. Economics also has the greatest number of completed concentrations (262), followed by FL&L (185). Psychology has 114 completed concentrations; there were 87 in Music and 81 in Literature. This year 71 more concentration proposals were filed than last year. Again this year, a reminder was mailed to all sophomores that concentration proposals should by filed by the end of the sophomore year.

HASS MINOR PROGRAMS

Now in its fourth year, the HASS Minor Program continues to grow. This year 497 minor applications were filed, compared to 443 last year. The three most popular fields in terms of applications filed are the same as last year, in

the same order: Economics (140), Music (72), and Literature (52). They are followed by three fields which are nearly tied: Political Science (30), German (29), and Writing (28). HASS Minors were received by 186 members of the Class of 1992; the order of popularity is the same as for total number of applications filed: Economics (48), Music (25), and Literature (21).

In addition to an increase in the number of students doing HASS Minors, six new minor programs were added to the existing 19. The six new HASS Minors in Regional Studies, which will be available as of AY1992-93, are: African and African Diaspora Studies, East Asian Studies, European Studies, Latin American Studies, Middle Eastern Studies, and Russian Studies.

HARVARD CROSS-REGISTRATION

1991-92 showed a considerable decrease in the number of MIT undergraduates taking subjects at Harvard: 146 students taking 161 subjects, compared to 217 students taking 238 subjects in 1990-91. There is no obvious reason for the decrease; students who do take classes at Harvard seem to be happy with them. Foreign languages continue to be the most popular field; 23 students took Chinese at Harvard, followed by 12 each in Italian and Korean.

COURSE XXI DEGREES GRANTED

Three students received their S.B. in Humanities in February 1992; 27 students completed the S.B. in June 1992, for a total of 30. Of the June graduates, 12 received joint degrees, seven in XXI-E and five in XXI-S. Another 12 students received degrees in a specific field within Course XXI. Three undesignated Humanities degrees were granted in June 1992.

COURSE XXI ENROLLMENT

In May 1992 there were 103 students who had declared a major in Course XXI. Of these, 37 were joint majors (19 in XXI-E and 18 in XXI-S). Literature had the most majors (27), followed by Writing (22) and History (15).

COURSE XXI HONORS AND AWARDS

Among the more notable distinctions and honors achieved by Course XXI majors this year were:

Phi Beta Kappa: Tona J. Hangen '92
Burchard Scholars: Haider A. Hamoudi '93, Naghmeh Sohrabi '94
I. Austin Kelly III Competition: Thomas C. Bruno '94
Peter J. Eloranta Award: Alexander P. Rigopulos '92
National Science Foundation Fellowship: Eric J. Zylstra '92
Robert A. Boit Writing Prize: Sandra Chen '92, David Towner '92
Boit Manuscript Prize: Joseph M. Miller '93
Friends of Music Award: Larry Taylor '93
Louis Sudler Prize: Alexander P. Rigopulos '92
Tau Beta Pi: Saeed N. Jaffer '92, Ona Wu '92

PHILIP S. KHOURY

Department of Economics

INTRODUCTION

The scientific and academic activities of the Economics Department continued at an intensive pace during the year. Members of the faculty also extended their participation with national and international policy issues in a number of areas. Although no new senior appointments were made, four junior faculty appointments were made in several areas. The Department was extraordinarily successful in recruiting new graduate students for the fall term in 1992.

FACULTY PERSONNEL

The Department was fortunate this year in being able to make four junior appointments. Associate Professor Ricardo Caballero, one of the most promising young macroeconomists today, accepted the Department's offer of an associate professorship effective July 1, 1992. He has been appointed the Castle Krob Career Development Associate Professor. Jushan Bai, who specializes in econometrics and is obtaining his Ph.D. from the University of California at Berkeley and Jonathan Gruber, a fiscal economist from Harvard were appointed as assistant professors effective July 1, 1992. Michael Kremer from Harvard will pursue post-doctoral studies in macroeconomics this coming year.

Associate Professor William Wheaton was promoted to full professor and was named Director of the Center for Real Estate. Assistant Professor Roland Benabou was promoted to Associate Professor.

Professor Jean Tirole resigned from the Department to accept an offer from the Université of Toulouse in France. However, he will continue his relationship with the Department as a visiting professor for the academic year 1992-93. Assistant Professor Danny Quah resigned his position and has accepted a position at the London School of Economics. Assistant Professor Thomas Lemieux also resigned and has accepted a position at the University of Montreal.

Senior faculty members on leave for this year or part of the year were Professor Peter Diamond, Professor Drew Fudenberg, Professor Paul Krugman, and Professor Tirole. Professor Krugman was at the Harvard Business School for the academic year, and Professor Tirole was at the Université of Toulouse. Professor Fudenberg was at the Université of Toulouse for the spring semester. Junior faculty members on leave were Professor Lemieux who spent the year at Princeton University, and Professor Quah who was on leave for the fall semester at the London School of Economics.

There were four visiting faculty and two visiting instructors this year. Professor Michael Bruno from the Hebrew University and Bank of Israel taught macroeconomics. Professor Robert Porter from Northwestern University taught industrial organization in the fall semester. Associate Professor Kala Krishna, an international trade economist from Harvard, taught international economics. Assistant Professor Klaus Schmidt from the University of Bonn taught microeconomic theory in the spring semester. Eduardo Engel from the University of Chile and Eran Yashiv from Hebrew University taught statistics and econometrics respectively.

The Department maintains its concern with increasing the representation of women and minorities in the economics profession. There were three offers made to women this year. However, these offers were declined. Two of these offers were declined because the candidate's spouses could not find employment in the Boston area.

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's class of 34 will include 13 international students and 12 women (36 percent). In the whole student body, 36 percent are from abroad, 24 percent are women, and six percent are minority. This year about 28 percent of our entering class have National Science Foundation Fellowships to begin their graduate studies

in economics studies.

Undergraduate enrollment declined this past year. We are, however, expecting an increase over the next few years because the thesis requirement is now optional. There were 81 undergraduate majors in economics and 140 undergraduate minors last year. The total enrollment in all undergraduate subjects in economics this year was three percent larger than last year.

FACULTY RESEARCH

Faculty research continues to be characterized by intensity and great productivity. Following are examples: "The Informativeness of Prices; Search with Learning and Cost Uncertainty" (Professor Benabou with Rob Gertner) "Exports and Wage Structure in Brazilian Manufacturing" (Assistant Professor Andrew Bernard); *Reform in Eastern Europe* (Professor Olivier Blanchard with Professor Rudiger Dornbusch, Professor Krugman, R. Layard, and L. Summers); "An Experimental Comparison of Dispute Rates in Alternative Arbitration Systems" (Assistant Professor Janet Currie with O. Ashenfelter, H. Farber, and M. Spiegel); "The Flow Approach to Labor Markets" (Professor Diamond); *Global Warming: Economic Policy Responses* (Professor Dornbusch with Professor James Poterba); "Comparing the Costs of Greenhouse Gas Emissions on Global Warming" (Professor Richard Eckaus); "Lessons from Moderate Inflation" (Professor Stanley Fischer); *Econometrics, Essays in Theory and Applications*, Volume II of collected works (Professor Franklin Fisher); "Technology and the Liberal Arts" (Professor Ann Friedlaender); "Testing for Price Anomalies in Real Estate Auctions" (Professor David Genesove with O. Ashenfelter); "Reporting Delays and the Incidence of AIDS" (Associate Professor Jeffrey Harris); "The Theory of Debt Based on the Inalienability of Human Capital" (Professor Oliver Hart with J. Moore); "Seasonal Adjustment of Trade Data" (Professor Jerry Hausman with R. Judson and M. Watson); "Expanding Competitive Opportunities in Electricity Generation" (Professor Paul Joskow); *Currencies and Crises* (Professor Krugman); "Uniform Convergence in Probability and Stochastic Equicontinuity" (Professor Whitney Newey); "The Limits of the Market and the Transformation of Socialism" (Professor Michael Piore); "Is the Gasoline Tax Regressive?" (Professor Poterba); *The Maze of Urban Housing Markets: Theory, Evidence and Policy*, University of Chicago Press (Professor Jerome Rothenberg with G. Galster, R. Butler, and J. Pitking); "Folk Theorems in Overlapping Generations Games" (Assistant Professor Lones Smith); "Hahn on the Share of Wages in National Income" (Professor Robert Solow); "Structuralist and Competing Approaches to Development Economics" (Professor Lance Taylor); "Soviet and Nazi Economic Planning in the 1930s" (Professor Peter Temin); "The Cost of Capital, Tax Reform and the Future of Rental Housing" (Professor Wheaton).

FACULTY HONORS

Professor Currie has been selected to be an NBER Olin Fellow for the 1992-93 academic year. Professor Diamond was named as the first Paul A. Samuelson Professor of Economics. Professor Dornbusch was awarded the Harms Prize from the Institute for World Economics, University of Kiel, Germany. Professor Fischer was appointed as Elizabeth and James Killian Professor. He was also appointed Honorary Professor in Universidad del Pacifico, Lima, Peru. Professor Hausman was appointed the John and Jennie S. MacDonald Professor. Professor Poterba was named to the NSF Advisory Panel in Economics. Professor Solow received an Honorary Doctorate from SUNY, Albany and an Honorary LLD from Harvard University.

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. Professor Blanchard is a member of the Organization Committee for the 1993 American Economic Meetings in Anaheim, CA. Professor Eckaus is a member of the Research Advisory Committee for the Consortium on Financing of Higher Education. Professor Fischer gave the Graham Lecture at Princeton University in April. Professor Friedlaender is a Trustee, RAND Corporation. Professor Genesove presented a paper at the annual meeting of the American Economic Association in New Orleans, January 1992. Professor Poterba gave the W.S. Woytinsky Lecture at the University of Michigan. Professor Rothenberg was named to the Editorial Board of the *Journal of Housing Economics*. Professor Solow gave the Sturc Lecture at Johns

Hopkins School for Advanced Studies and the Tinbergen Lecture at the Netherlands Economic Association. Professor Solow is also a member of the committee evaluating graduate teaching and research in economics in Sweden. Professor Taylor was the research coordinator for the World Institute for Development of Economics Research in Helsinki, Finland. Professor Wheaton was named Director of the Center for Real Estate.

DEPARTMENTAL GIFTS AND RESEARCH GRANTS

The Department continues to receive substantial financial support from its alumni and friends. The Department is establishing a fund in the name of Donald H. Layton to support phase II of the development of the Department's computer cluster.

The Department has developed a computer cluster which offers a range of computing resources for faculty and graduate students. In phase I, the computer cluster was developed for students to do course work and write thesis, and to enable researchers to handle large data sets. Phase II will expand the cluster to support all the Department's faculty and student's needs.

The World Economy Laboratory (WEL) in the Department was established to make resources available to support policy research and to communicate research findings more effectively to a broad audience. WEL was established in January 1992 with Professor Fischer as director and an executive committee consisting of Professors Dornbusch, Joskow, Poterba, and Temin.

In the first six months of operation WEL has obtained two Ford Foundation grants. In addition, WEL has begun establishing a base of associate members. The first three supporting members of the WEL are General Electric, Kodak, and the Institute of Mitsui & Co. for Trade and Economic Studies.

The National Science Foundation awarded Professor Newey a grant for his project entitled, "Nonparametric Estimation of Econometric Models."

The Castle Krob Development Chair was activated this year with the appointment of Ricardo Caballero. The Chair had been funded by John Castle and was awaiting a suitable inauguration.

PETER TEMIN

Department of Humanities

Anthropology/ Archaeology Program

In 1991-92, the Anthropology/Archaeology Program continued developing several initiatives in teaching and research in collaboration with other groups in the Institute. Professors James Howe and Jean Jackson participated in the Graduate Program in the History and Social Study of Science and Technology, now completing its fourth year, serving on a search committee that has successfully filled one vacancy, and potentially another. Hugh Gusterson, currently finishing a post-doctorate position at the School of American Research, will hold a joint appointment as Assistant Professor of Anthropology and Science Studies.

Associate Professor Arthur Steinberg served one semester as director of the Integrated Studies Program (ISP); Professor Steinberg, the first Class of 1960 Fellow, has become very involved in introducing ISP-like programs in the secondary school curriculum. He and two other faculty members received a Pew Foundation grant for an MIT summer teacher institute.

The A/A Program's lecture series on "Peoples and States: Ethnic Identity and Conflict," co-sponsored by the Center for International Studies (CIS) with funding from the MacArthur Foundation and the Office of the Dean of the School of Humanities and Social Science (SHSS) finished a third successful year and has scheduled nine speakers for what promises to be an equally exciting fourth year.

Four faculty members have books in progress. Professor Martin Diskin is completing his manuscript on The Rural War in El Salvador for Westview Press, and Dorothy Hosler, Esther and Harold E. Edgerton Assistant Professor of Archaeology and Ancient Technology, is completing her book, The Sounds and Colors of Power in Ancient West Mexico, for MIT Press. Professor Howe wrote a substantial portion of his manuscript, A People Who Would Not Kneel: Panama, the United States, and the San Blas Kuna. Professor Jackson was offered contracts from two publishers for her book in progress, Camp Pain: Building and Resisting Community in a Chronic Pain Center.

Professor Hosler has three articles on ancient Mexican metallurgy in press. Professor Jackson published a chapter in an edited book on chronic pain and two articles on ritualized sexual violence in the Northwest Amazon. Professor Howe has a book chapter, on paired Kuna myths, and three articles in press. Professor Steinberg has an article on Venetian painting in press. Professor Heather Lechtman published an article on America's vanishing metalsmiths and has a book chapter in press. She and Professor Hosler hold joint appointments in A/A and the Center for Materials Research in Archaeology and Ethnology (CMRAE) (please see CMRAE'S President's Report for further information).

A/A faculty presented papers in Memphis, Puerto Rico, Chicago, Pittsburgh, Albany, Phoenix, Bogotá, Los Angeles, and New Orleans. Professor Lechtman gave the Walter W.S. Cook Lecture at the Institute of Fine Arts, New York University.

Professor Steinberg spent his sabbatical in the spring in Venice, Italy, analyzing Venetian historical myths. Professor Hosler returned to Ecuador for further fieldwork in ceramic analysis. Professor Jackson returned to the Vaupés, Colombia, to continue research on Amazonian Indian rights mobilizing.

Professor Hosler received funding from the John D. and Catherine T. MacArthur Foundation for work with a UROP student on remote sensing and identification of Mexican cassiterite ores used in prehistoric bronze production. Professor Diskin served as a consultant for Oxfam-America's Central American research program and is editing the research reports for publication.

Professor Howe won HASS-D status for a new subject, "1492 and After: Europe and the Peoples of the New World." The students in Professor Hosler's HASS-D subject, "The Human Past: Introduction to Archaeology" excavated the dirt pile resulting from biology building construction, with funding provided by the SHSS Dean's Office. Professors Steinberg and Jackson supervised senior theses, and Professor Hosler was a freshman advisor.

Professor Steinberg served on four MIT committees. Professor Lechtman is the Convener for the MIT Women's Faculty Network. Professor Jackson organized an IAP activity, spoke to the Burchard Scholars, the Emma Rogers Society, the MIT Wives' Group, and was a discussant and panelist for two Cultural Studies Conferences. She was also on the editorial board for the MIT Faculty Newsletter and served on seven committees. Professor Howe served on two committees and spoke to the Cultural Studies Biographers' Roundtable. Professor Hosler spoke to LUCHA, the MIT undergraduate Mexican-American student group, and gave an STS colloquium.

The A/A 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. Professor Howe, with support from the SHSS Dean's Office, is attempting to locate candidates in Latin American and Hispanic studies.

JEAN JACKSON

Foreign Languages and Literatures Section

While building on the accomplishments of the past year and responding to the student demand for internationalization of the curriculum, the Foreign Languages and Literatures Section continued to strengthen its existing language offerings and to expand and develop the East Asian component of the program. Under the guidance of Dr. Yih-jian Tai, Visiting Assistant Professor of Chinese, the program in Chinese Language, Literature and Culture was instituted with grant funds from the Chiang Ching-kuo Foundation. The student response to these offerings, in both language and literature, has been overwhelmingly positive. In fact, 22 students were turned away due to over enrollments and because their bilingual backgrounds were too advanced for beginning classes. Next year, we will begin to offer upper-level subjects in Chinese. The Dean of Humanities and Social Science (Philip Khoury) and the Assistant Dean for Development (David Lundberg) recently made a fund raising trip to Asia. As a direct result of that trip, there is the expectation of a major gift in the near future to support the continued growth and development of Chinese at MIT. The Section's commitment to making junior faculty and full-time lecturer appointments was evidenced by the appointments of Martin Roberts, Assistant Professor of French Studies, Bernd Widdig, Assistant Professor of German Studies, and Ellen Crocker and Monika Totten, Lecturers in German, effective July 1, 1992. These appointments were the result of national searches.

Foreign Languages and Literatures faculty and staff working in the area of interactive language learning technology continue to provide national leadership. This year, Professor Shigeru Miyagawa, Associate Professor Suzanne Flynn and Senior Research Scientist Janet Murray were awarded a grant from the Provost/NEC Fund for the development of a Japanese and English as a Second Language interactive videodisc project. It is the first time that this award has been granted to a Humanities project; at the present time Professor Miyagawa is in Japan conducting research and filming for this project. A substantial level of research support from a number of other sources continues to fuel FL&L interactive videodisc projects, including funding from the Consortium for Language Teaching and Learning and from the National Endowment for the Humanities. Senior Lecturers Gilberte Furstenberg's and Douglas Morgenstern's groundbreaking work with French and Spanish videodiscs continues to gain national and international attention. Both "A la rencontre de Philippe," and "Dans le quartier St. Gervais" will be published by Yale University Press. The following publications in the field of pedagogy and technology were either published or are in press: Dr. Murray's "Restructuring of Space, Time, Text and Story" (in Senior Lecturer Edward Barrett's *Social Construction of Knowledge*), Senior Lecturer Morgenstern's "Shifting Paradigms, Shifting Sands: Interactive Multimedia for Language Learning," (in *Simulation and Gaming: An International Journal of Theory, Design, and Research*), and the third edition of Lecturer Crocker's German language workbook and lab system *Neue Horizonte* (D.C. Heath), co-authored with Dr. David Dollenmayer.

The Foreign Languages and Literatures faculty continues to focus their research in the areas of literary and cultural studies, and in linguistics. Associate Professor Isabelle de Courtivron's biography *Clara Malraux: Une femme dans le siècle* (Editions de l'Olivier/Le Seuil, 1992) appeared in April and her article on Violette Leduc was published by Greenwood Press in the Fall. Visiting Assistant Professor Bernd Widdig's book *Männerbünde und Massen. Zur Krise männlicher Identität in der Literatur der Moderne* (Wiesbaden: Westdeutscher Verlag, 1992), and his article "Melancholie und Moderne: Wolfgang Koeppens Der Tod in Rom," in *Germanic Review* (1991) were published this year in Germany. Articles and edited volumes account for a significant portion of the Foreign Languages and Literatures faculty and staff scholarly achievements: excerpts of Professor Edward Baron Turk's book "Child of Paradise," were published in French translation in Genevieve Sellier, *Les enfants du pardis* (Paris: Nathan, 1992) and his article "Deriding the Voice of Jeanette MacDonald: *Notes on Psychoanalysis and the American Film Musical*" (Camera Obscura No. 25/26), was published this year. Associate Professor Elizabeth Garrels' article "Traducia a America: Sarmiento y el proyecto de una literature nacional" in *Revista de Critica Literaria La timoamericana* (Lima, Peru and Pittsburgh, PA.) will appear in 1992. Visitng Assistant Professor Monika Totten's article " Zwischen gestern and morgen: DDR-Autorinnen aus amerikanischer Sicht," in Ute Brandes (ed.) *Protokoll-Literatur von Frauen: Alltagsgeschichte im Dialog* (1992). Lecturer Elena Semeka's "Folklore and Literature: Pushkin's *The Captain's Daughter*," is in press. In the field of linguistics, Professor Catherine Chvany published "Multi-level markedness in Russian, English and Bulgarian," in T. McAuley, A. Mackie and C. Simmons (eds.) *Papers in*

General and Computational Linguistics (1992), and "On paradigm geometry" in M. Guiraud-Weber and C. Zaremba (eds.) *Linguistique et Slavistique* (Publications de l'Université de Provence, 1992). Professor Flynn's "Government-Binding: Parameter Setting in Second Language Acquisition," will be published in the Fall in C. Fergusonn and T. Huebner (eds.) *Crosscurrents in Second Language Acquisition and Linguistic Theory.*

FL&L faculty and lecturers are professionally engaged in widely ranging fields and many have continued to give lectures nationally: at Harvard University (Professor de Courtivron, Professor Widdig, Senior Lecturer Furstenberg), the Modern Language Association (Professor Widdig), the American Association of Applied Linguistics, Cornell University, and Michigan State University (Professor Flynn, Visiting Assistant Professor Martohardjono), Dartmouth College (Professor Totten), and Arizona State, Northeastern and Illinois-Wesleyan Universities (Senior Lecturer Furstenberg), and internationally: University of Paris VII (Professor Chvany), the Universitat de Girona (Professor Harris), First Annual European Conference on Second Language Acquisition held in Salzburg, Austria (Professors Flynn and Martohardjono), and Yonsei University in Seoul, Korea (Professor Flynn). Other professional activities are wide ranging and include: Dr. Murray is a panelist/reviewer for the National Endowment for the Humanities, Professor Flynn is Associate Editor for *Linguistic Review* and Senior Lecturer Douglas Morgenstern sits on the Advisory Board for WGBH *Destinos.* Professor Chvany received the Distinguished Career Achievement Award for Outstanding Contributions to Scholarship at the 50th Anniversary celebration of the American Association of Teachers of Slavic and East European Languages (AATSEEL). Associate Professor Margery Resnick was honored this year with the "Faculty Member of the Year" award from the MIT Panhellenic.

Foreign Languages and Literatures faculty have demonstrated commitment to the Institute by serving on Committees such as the President's Calendar Committee, the Killian Prize Committee, the Equal Opportunity Committee, the Regional Minors Committee, the MIT Committee on Academic Computing, and the Committee on the Writing Requirement, among others.

The number of majors in Foreign Languages and Literatures remains low (six), however, the number of concentrators has increased markedly (446) and the number of minors has also shown a significant rise (78). Spanish continues to have the largest enrollments (359), followed by French (351), German (261), English as a Second Language (257), Studies in International Literatures and Cultures (252), Japanese (249), Russian (118), and Chinese (69). FL&L faculty and staff received some of the highest ratings in the Student Course Evaluation Guide.

This year, the goal of beginning to rebuild the ranks of junior faculty was successfully accomplished with the appointment of: Martin D. Roberts, Assistant Professor of French Studies, and Bernd Widdig, Assistant Professor of German Studies. FL&L has placed significant importance on making full-time appointments in order to decrease the number of part-time and visiting faculty. For AY 1992-93, Foreign Languages and Literatures will have reduced the number of part-time and visiting faculty by approximately 42%, from AY 1991-92. In 1991-92, national searches were conducted to hire two full-time lecturers in German: Ellen Crocker and Monika Totten. FL&L continued to be an Institute leader in hiring women; presently women constitute more than 60 percent of the Section faculty and staff.

Finally, Professor Robert Emmet Jones retires at the end of this year, after more than 25 years of distinguished service to the Institute.

ISABELLE DE COURTIVRON

PROMOTIONS AND NEW APPOINTMENTS

The History Faculty welcomed its seven new members in the fall. They introduced new subjects and actively pursued their research. We spent most of our time acculturating the new colleagues. In addition, Associate Professor Harriet Ritvo will be promoted to Full Professor effective July 1, 1992, when she will also assume the post of Associate Dean of the School of Humanities and Social Science. Assistant Professor Douglas Forsyth will be promoted to Associate Professor effective July 1, 1992. He also received the Class of 1942 Career Development Chair. Professor Jed Z. Buchwald will join the faculty as of July 1, 1992 with a joint appointment in History and STS, and will serve as Director of the new Dibner Institute for the History of Science and Technology.

Having made significant progress in affirmative action for women and minorities last year, the faculty now includes five women and one African-American. We conducted no new national searches this year. We have begun inquiries about candidates for a post in Latin American History, our most important priority, in collaboration with the faculty in Anthropology. We added one woman to the support staff, hiring Leslie Torrance in the fall.

RESEARCH AND PUBLICATIONS

1991 was a banner year for Luce Professor John Dower. The onset of the fiftieth anniversary of Pearl Harbor brought him many demands for interviews with newspapers and television stations in the US and Japan. He presented a paper at a conference at Pearl Harbor in December, entitled "War Without Mercy: A Review of Japanese and American Attitudes in 1941". As a new member of the MIT faculty, he gave many talks about US-Japan relations to groups at the Institute, including the Burchard Scholars, Phi Beta Kappa, and the Center for International Studies, where he spoke on "Convergence and Divergence: Using Japan to Talk (or not Talk) about War and Capitalism". He also spoke to the US State Department Foreign Service Institute on the topic "The US & Japan: 50 Years of War and Peace". His research work this year focused on writing a chapter of his manuscript tentatively titled "Reinventing Japan", which discusses the treatment of the emperor in the aftermath of Japan's surrender.

Dean Philip Khoury published "Continuity and Change in Syrian Political Life: The Nineteenth and Twentieth Centuries" (*American Historical Review*) and "Syrian Political Culture: A Historical Perspective" in *Syria: Society, Culture, Polity*. Professor Pauline Maier published "The Debate over Incorporations: Massachusetts in the Early Republic" in *Massachusetts in the Early Republic*. Professor Bruce Mazlish published "The Question of 'The Question of Hu'" in *History and Theory* (a discussion of Jonathan Spence's book on China),as well as "A Triptych: Freud's Dream, Haggard's *She* and Bulwer Lytton's *The Coming Race*" (*Comparative Studies in Society and History*), and organized an international conference on Global History. Professor Ritvo published "Toward a More Peaceable Kingdom" (*Technology Review*), an article discussing ethics of animal experimentation, "Possessing Mother Nature: Genetic Capital in 18th-Century Britain" (*Early Modern Conceptions of Property*), "Race Breed and Myths of Origin: Chillingham Cattle as Ancient Britons" (*Representations*), and "The Animal Connection" in the volume *Humans, Animals and Machines: Boundaries and Projections*. Associate Professor Peter C. Perdue contributed chapters to *Nourish the People: The State Civilian Granary System in China, 1650-1850* (University of Michigan). Professor Alexander Keyssar delivered a paper on "Trends in Unemployment in the US" and continued working on a book on the history of the right to vote in the US. Professor Forsyth, while on leave, completed revisions on his manuscript, "The Crisis of Liberal Italy: Monetary and Financial Policy in Italy, 1914-22", forthcoming from Cambridge University Press. Assistant Professor Anne McCants published "Internal Migration in Friesland: 1750-1805" in the *Journal of Interdisciplinary History*. Assistant Professor Elizabeth Wood delivered papers on "The Trial of a Prostitute: Theater and Political Ritual in Post-revolutionary Russia" and "The Woman Question in Revolutionary Practice".

HONORS AND AWARDS

Professor Forsyth received funding for an international research project on "Financial Institutions and Monetary Regimes in Europe from the 1930s to the 1990s" from the Center for European Studies at Harvard, the Robert-Bosch-Stiftung in Germany, and the Center for International Studies, MIT. Assistant Professor Robin Kilson participated in a program funded by the Pew Foundation to introduce the case study method into college teaching, which she will use to redesign her course on European imperialism. Professor Perdue received the Levitan Prize for his project on the expansion of the eighteenth-century Chinese empire into Central Asia.

EDUCATION

Our new faculty initiated many popular subjects, including "Black Studies", "World War II in Asia", "Family, Work, and Leisure in the US", and "Soviet Politics". Associate Professor Arthur Kaledin joined with colleagues in Anthropology and Physics to teach "Ideas of World Order". Professor Merritt Roe Smith generated great enthusiasm for his course on "Civil War and Reconstruction". Assistant Professor Jon E. Lendon earned rave reviews for his survey courses on Greek and Roman civilizations.

Historians joined in the design of new Regional Studies minors for undergraduates in East Asian Studies, African Studies, Middle Eastern Studies, and European Studies. History concentrators totalled 88, and minor enrollments totalled 21. Five seniors completed theses this year. Topics included propaganda in China during the Pacific War (Ona Wu), the political thought of James Madison (Jennifer Alpert), the history of Las Vegas (John Ward), experiences of Civil War Nurses (Amy Lamphier), and issues in contemporary Texas politics (Chris Bera).

Associate Professor William Watson, who is also Headmaster of Baker House, conducted a survey of sexual harassment there.

In graduate education, the faculty participated in the joint Ph.D. program in the History and Social Study of Science and Technology by teaching the Historical Methods seminar, serving on the Admissions and Steering Committee, and providing reading courses for students preparing for general exams. Professor Wood taught a graduate seminar on "Gender and Politics" for the Political Science department.

OTHER ACTIVITIES

The Kenan Sahin lecture series led off its first year with lectures by Visiting Scholar Ronald Edsforth on "Working Class Politics in the United States and Britain, 1945-1970" and Professor Victoria de Grazia of Rutgers University on "Nationalizing Women: The Competition Between Fascist and Commercial Cultural Models in Mussolini's Italy". Professor Mazlish jointly directed the Humanities Faculty Workshop, and Professor Keyssar participated in the Industrial Relations Workshop. Dean Khoury continued to direct the Bustani Seminar on Middle Eastern Studies and organized an international conference on "Urban and Spatial Reconstruction in Lebanon", held at MIT in September 1991.

The Cultural Studies Project gathered new momentum, with Professor Dower on the Advisory Board and Professors Mazlish, Ritvo, and Perdue on the Steering Committee. Historians staged two conferences with the project's support this year. "Engendering China", a conference examining Chinese history and politics from a gender perspective, included discussion by Professor Wood of comparisons with the woman question in early Soviet Russia, and women's studies activists from the People's Republic explaining their efforts to organize a new field of study in China. "Pomp and Circumstance: Political Uses of Public Culture" assembled historians, anthropologists, architects, and literary scholars to discuss monuments, processions, and carnivals around the world. Professor Mazlish helped organize "The Idea of Progress" with support from the Dibner Institute. Historians also helped to organize the Women and Politics lecture series, the visit of Toni Morrison, and presentations of Middle Eastern Music. At the end of the spring term, Professors Khoury, Dower, and Perdue jointly discussed "What Can the West Learn From the East" as part of Technology Day.

PETER C. PERDUE

The Literature Faculty has continued to be a highly productive teaching and research faculty whose work in film and media and various forms of cultural study, as well as in literary scholarship are widely respected and increasingly influential in the profession.

Academic Program and Student Enrollment
During the past year, 1107 students enrolled in Literature subjects, 27 were registered as Literature majors, 54 as minors, and 169 as concentrators in Literature for the HASS requirement. The Literature Faculty continues to participate actively in the curricular reforms of the School: this year, Professor Cynthia Wolff's innovative HASS-D subject, Decoding the Narratives of American Culture, was offered for the first time. Professor Peter Donaldson's seminar on the relationship between literature and technology, Technologies of Humanism, will be offered for the first time in 92-93.

Research and Publication
Professor Donaldson completed a study of the use of computer imagery in *Prospero's Books*, a film adaptation of Shakespeare's *The Tempest*. Professor David Halperin continued his research on gender and erotic theory in classical Greece with an article on "Plato and the Erotics of Narrativity" in *Methods of Interpreting Plato and his Dialogues* (*Oxford Studies in Ancient Philosophy*, Supplement 2). Associate Professor John Hildebidle published poems, essays, critical studies and short fiction in *Atelier*, *The American Literary Review* and in several collections. Professor Ruth Perry published several essays including a study of "Mary Gordon's Mothers" in *Novel Mothering*, ed. Maureen Reddy (University of Tennessee Press) and published more than twenty reviews in *Signs*, *Women's Review of Books*, *Eighteenth Century Fiction* and *Science and Society*. Professor Perry also continued her study of the family and the novel in eighteenth-century culture. Professor Stephen Tapscott continued to produce critical work on other poets, contributing an essay on Charles Simic to a volume of collected essays, and in addition several of his own poems were published. Professor Irene Tayler continues research on "Veiled Woman: the Evolution of an Image" and completed a study of gender in Wordsworth. Professor Wolff continued her research on Harriet Beecher Stowe, began work on a new project on the relation of classic American literature to contemporaneous African American and women's writing, published several essays including "'Margaret Garner': A Cincinnati Story" in *The Massachusetts Review*, and completed a study of the motif of masquerade in *The House of Mirth*. Assistant Professor Mary Fuller has completed a study of classical allusion in *The Tempest* and is revising her dissertation on Renaissance accounts of America. Assistant Professor Louis Galdieri has completed a study of More's Utopia and is revising his dissertation on Thomas More and Renaissance historiography for publication. Associate Professor Rita Goldberg is writing a book on compassion and the rise of the victim in eighteenth century literature. Assistant Professor Henry Jenkins III has two books in press, a book on film comedy and its vaudeville roots (Columbia University Press) and a study of television fan culture (Routledge). He continues work on a book on science fiction audiences under contract at Routledge. Associate Professor Theoharis C. Theoharis continued work on his study of Aristotelian and Nietzschean theories of dramatic action in the works of Ibsen, Beckett and O'Neill.

Conferences and Invited Addresses:
Members of the faculty have also presented their work at a number of conferences including meetings of the Shakespeare Association of America, Mid-America Medieval Association, Renaissance Society of America, Center for Literary and Cultural Studies, Harvard University, Sixteenth Century Studies Conference, American Philological Association, Conference on Feminism, Philosophy and Science (Valencia, Spain), World Shakespeare Congress (Tokyo), Society for Cinema Studies, International Congress of Comparative Literature (Tokyo), Modern language Association, Society for Literature and Science, Society for Philosophy and Literature, Northeast Association for Eighteenth Century Studies, Edith Wharton International Society (Paris), American Literature Association, The International Society for the Study of European Ideas (Aalborg, Denmark), East Anglia University Conference (Norwich, U.K.), International Television Studies Conference (London)and have delivered public lectures and presentations at the University of Oregon (Eugene), State University of New York (Buffalo), University of Chicago, Brooklyn College, Vanderbilt University, Bennington College,

University of Michigan, University of Illinois, Boston University, Cornell University, Princeton University, Tufts University, Boston College Law School, Harvard Law School, Vassar College, Indiana University, University of Iowa, Wesleyan University, Hampshire College, and the University of California, Berkeley.

Service, Grants and Awards:
This year, Professor David Thorburn continued to serve as Director of the Cultural Studies Project, to which many members of the Literature Faculty also contributed. In March, Professor Donaldson convened a conference on Shakespeare: Text, Performance, Hypermedia sponsored by Cultural Studies, which provided an opportunity for scholars in the rapidly developing area of Shakespeare film and performance studies to interact with some of the innovative work being done in hypertext and hypermedia. At this conference, the Shakespeare Interactive Research Group (Professor Donaldson, Literature, Dr. Janet Murray, Athena Language Learning Project, and Professor Larry Friedlander, Stanford University) demonstrated a prototype of its system for linking electronic texts of Shakespeare plays to corresponding performances on disc. In June, the Shakespeare Interactive Research Group was awarded a major grant by the National Endowment for the Humanities (Reference Division) for the development of a Demonstration Archive based on the Oxford text of Hamlet and the film versions of the play directed by Laurence Olivier and Franco Zeffirelli. Professor Alvin Kibel was awarded a planning grant by the American Academy of Arts and Sciences for an international conference on the cultural implications of the end of the twentieth century. Professor Kibel was also selected to initiate a new series of Seminars at the National Humanities Institute. Professor Tapscott was designated Master Teacher by the Knight Writing Center at Cornell, and served as Visiting Poet at University of Massachusetts, Boston and at the Tyrone Guthrie Center (Ireland) and as artist-in-residence at the Virginia Center for the Creative Arts (Sweet Briar) and at the Mishkenot Sha'ananim (Jerusalem). Professor Perry served as Director of Women's Studies at M.I.T. and as Chair of the Steering Committee of the Graduate Consortium of Women's Studies at Radcliffe, and convened the Conference "Engendering Environmental Thinking" at M.I.T. Professor Wolff gave the keynote address at the International Edith Wharton Society in Paris, and was Distinguished Lecturer at Indiana University. Professor Halperin founded (with Carolyn Dinshaw) GLQ: A Journal of Lesbian and Gay Studies and edits two series of books: "The New Classical Canon" (Routledge) and "Ideologies of Desire" (Oxford). And finally, Professor Jenkins was awarded the Harold E. Edgerton Award, in recognition of distinguished teaching, research and service to the M.I.T. community.

The Literature Faculty continues, in its research, teaching, and participation in the life of the Institute, to maintain a high standard of scholarly excellence, to contribute centrally to new and emerging fields in the humanities, and to grapple, energetically, with questions of diversity and tradition, in an effort to define -- and continually redefine -- the role of humanistic study in technological society.

PETER S. DONALDSON

Music and Theater Arts Section

Diversity of personnel and innovative programming have marked the activities of Music and Theater Arts during this academic year.

The theater program continued its practice of appointing women and underrepresented minorities to long and short-term Guest Artist Residencies. The Roxbury Outreach Shakespeare Ensemble under the direction of Decima Francis was in residence for the entire year, offering Theater Workshops for minority students each semester and bringing minority junior and senior high school students to campus for performances. Actor Jerome Butler received a full-time teaching residency during which he and his students developed an interactive video project with minority inmates of a medium security prison in California. Professor Rosa Luisa Marquez of the University of Puerto Rico and her collaborator, graphic artist Antonio Martorell, produced an extraordinary multi-media exhibit during IAP with the cooperation of Visual Arts. We are happy to report that Professor Marquez will join us for a full-year residency in AY 1992-93.

New to the music program this year were appearances in several academic classes by performers who were brought to campus under an Artist-in-Residence Program sponsored by the Office of the Arts. Exposure to the music of different cultures featuring a wide range of instruments were hallmarks of these appearances. Guest Artists from around the world included I Wayan Sadra, Simon Shaheen, Aché, Israel Cachao Lopez, the Carnegie Mellon Trio, and The Rova Saxophone Quartet.

Affirmative action searches during the year resulted in an increase in the number of women in the Section. Janet Sonenberg will become the first female faculty member in the theater program when she assumes her duties as Assistant Professor of Theater Arts next fall. Composer Elena Ruehr will join a distinguished group of hitherto all-male colleagues teaching theory and composition in her new post as a full-time Lecturer in Music. Even the Headquarters Office became more diverse with the hiring of its first male Administrative Assistant.

Controlled expansion in the field of ethnomusicology was furthered by the appointment of George C. Ruckert as a Lecturer in Music. Mr. Ruckert is a specialist in Northern Indian Music and will join our staff in the Fall of 1992. The Section also approved the proposal of ethnomusicologist and Assistant Professor Evan Ziporyn to build a Balinese gamelan with the aid of MIT students and eventually form MIT's first Gamelan Ensemble.

More than 130 concerts were presented under Section sponsorship. These included performances by the eight student ensembles, individual student recitals, chamber music society, and advanced performance students. Professional musicians were heard in the chapel series, musicians behind the desk series, faculty and staff series, and the guest artist series. Of special note were two performances by the MIT Symphony Orchestra under the baton of Dalia Atlas, Visiting Professor of Music from the Technion in Haifa, Israel, and one of the few women conductors in the world. Another woman, Jee-Hoon Yap '91, was the featured soloist at the May concert with a brilliant performance of the Rachmaninov *Piano Concerto No. 3.*

Student accomplishment continues to be recognized at both Institute and Section level. Music major Alexander P. Rigopulos '92 won the Sudler Prize, as well as an Eloranta Fellowship, while a member of the Musical Theater Guild, Tarik K. Alkasab '92, received one of the two Laya and Jerome Wiesner Awards. Two new Section prizes were established this year: the Gregory Tucker Memorial Prize for excellence in music and the Joseph D. Everingham Award for a single creative accomplishment in theater. Two Tucker prizes were given--one to Eran Marcus '93 and the other to Mark Messier '93. Messier, together with fellow musician, Kevin Karnes '94, was also designated a Ragnar Naess Scholar. The Everingham Award went to Karen Philpott '92, and Andrea Leszek '93 won the Edward S. Darna Award.

We note also that enrollments in theater arts have doubled since the new theater curriculum was instituted, rising from 175 in AY1989-90 to a new high this year of 344. Music enrollments continue to be strong with 1174 students taking music subjecs for credit in 1991-92. Three music majors, 25 minors, and 80 concentrators received their MIT degrees in June, together with 6 minors and 18 concentrators in theater arts. In addition, one student has received approval for the Major Departure in Theater Arts.

Faculty, too, were recognized for their achievements. Associate Professor Lowell E. Lindgren was promoted to Full Professor, and Associate Professor Peter Child was promoted to tenure, effective July 1,1992. Professor John Harbison received an honorary degree from Indiana State University last September and was inducted into the American Insitute of Arts and Letters in May. Professor Ziporyn received the Wade Award from MIT, the first faculty member in Humanities to be so honored, and was also chosen to receive the Class of '58 Career Development Chair.

Artistic premieres included Professor Alan Brody's plays, *Greytop in Love* at the Missouri Repertory Theater in Kansas City, and *Invention for Fathers and Sons* at the American Jewish Theater in New York City; Professor Child's *Tableaux I* by Collage and *Arrows to the Sun* at the Music School at Rivers; Professor Harbison's *The Rewaking* by the Juilliard Quartet with soprano Benita Valente in Pittsburgh, Boston, and Washington and *Due Libri* by the New York Philomusica with mezzo soprano Laraine Hunt in New York City. Professor Ziporyn premiered his own works in Toronto, San Francisco, and New York. In a presentation by NUarts, Senior Lecturer Beth Soll premiered *Mozart & Cosmology*, a collaborative work with Paul Earls from the Center for Advanced Visual Studies. Centaur Records released Lecturer David Deveau's debut compact disc featuring unfamiliar works of Franz Liszt.

Performances, lectures, and publications kept faculty and staff busy all over the world. Professor Marcus Thompson played at chamber music festivals in Alaska, California, Colorado, Maine, and Washington State, toured Holland as a member of the Amsterdam Chamber Music Society, was soloist in a PBS inaugural concert in Lincoln, Nebraska, and premiered a new string trio for a series at the University of Maryland. Lecturer Deveau was soloist with the Boston Pops, Pacific Symphony, and Minnesota Orchestras; he gave recitals in Montana, Colorado, Califor nia, Washington, and at Carnegie Mellon University where he was also a Visting Artist/Lecturer. Professor Lindgren wrote the introduction and edited seven essays which he titled "Bits and Pieces: Music for Theater" for publication as the entire spring issue of the *Harvard Library Bulletin*. Professor Jeanne Bamberger lectured at the San Francisco Exploratorium, the University of Montreal, and for the American Education Research Association. Assistant Professor Martin Marks accompanied two Harvard Film Archive series and gave a performance/lecture at the Annual Meeting of the Society for Cinema Studies in Pittsburgh.

The Section accepted with regret the resignation of Lecturer Jamshied Sharifi '83 who has directed the MIT Festival Jazz Ensemble since 1985. We also bid farewell to the former Director of the BU School of Music, Robert Sirota, who held an interim lectureship in the Section before becoming Chair of Music at NYU.

ALAN BRODY

Program in Writing and Humanistic Studies

The Program in Writing and Humanistic Studies performs a vital teaching service at the Institute. 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. Camille Paglia and Samuel Delany presented lectures this year entitled "Crisis in the American Universities" and "The Rhetoric of Sex, the Discourse of Desire," respectively; MacArthur Fellow Jorie Graham read from her most recent collection of poems; and a memorial poetry reading was held in honor of James Schuyler including readings by many of Schuyler's contemporaries.

Professor Alan Lightman published three new books entitled *Ancient Light Our Changing View of the Universe* (Harvard University Press, 1991), *Great Ideas in Physics* (McGraw-Hill, 1992), and *Time for the Stars Astronomy in the 1990s* (Viking Penguin, 1992). Visiting Writer Ruth Whitman published a collection of her poems entitled *Laughing Gas: Poems New and Selected 1963-1990* (Wayne State University Press, 1991). Associate Professor Harriet Ritvo was promoted to the rank of Professor, effective July 1, 1992. She will also assume an appointment as Associate Dean of the School of Humanities and Social Science, effective July 1, 1992. Assistant Professor Thomas Simmons resigned from the Program and will assume a faculty position at the University of Iowa. Professor Kenneth Manning continues his project on "Blacks in American Medicine, 1860-1980." He will be on sabbatical leave for the coming spring term. Professor James Paradis continues his work on Samuel Butler. Professor Elżbieta Ettinger Chodakowska continues her biography of Hannah Arendt. Associate Professor Rosalind Williams assumed the position of Associate Chair of the Faculty and Chair of the Committee on Undergraduate Program, effective July 15, 1991. She continues her work on the cultural history of technology. Lecturer Ellen Cooney published two stories in *The New Yorker* magazine. We have undertaken a search for a new professor of fiction writing, and are about to begin a search to replace Professor Simmons.

In 1991-92, Writing and Humanistic Studies had 62% women on its total staff and 43% women on its professorial staff. Currently, the Program has one member of an underrepresented minority at the rank of full professor. We made no new professorial hires in 1991-92. Over the coming year, we plan to hire two new professors, one junior and one senior, and continue to have as a high priority the recruitment of underrepresented minorities to the faculty.

Professor Manning stepped down as Head of the Writing Program and was replaced by Professor Lightman, effective July 1, 1991.

ALAN P. LIGHTMAN

Department of Linguistics and Philosophy

INTRODUCTION

After two decades of relative stability in its educational programs, the Department of Linguistics and Philosophy and the Department of Brain and Cognitive Sciences have together initiated a new graduate research training program: "Language: Acquisition and Computation." The new program is under the co-directorship of Associate Professor David Pesetsky and Professor Kenneth Wexler with the involvement of 19 faculty members from both departments. This major innovation in the educational and research program of the Department was made possible by a grant of $1.3 million from the National Science Foundation and the generous support of the Institute. It formalizes longstanding educational and research relationships among linguistics, cognitive science, and computational linguistics, and aims to form a new generation of scientists for whom the present boundaries between linguistics and the cognitive sciences will no longer exist.

There have been no new appointments to the Department this year, but an offer to a senior philosopher is outstanding. In a very difficult job market, the Department continues to be unusually successful in placing graduates of its two doctoral programs. Recent graduates have accepted regular faculty appointments at, among others, New York University, Princeton University, the University of California at Irvine, the University of Iowa, and the University of Hokkaido.

RESEARCH: LINGUISTICS

Recent work in syntactic theory has moved linguistics closer to a minimalist "theory of language that takes a linguistic expression to be nothing more than a formal object that satisfies the interface conditions [of phonetic and logical form] in an optimal way", bringing the work in syntax a tantalizing step away from demonstrating that "the basic principles of language are formulated in terms of notions drawn from the domain of (virtual) conceptual necessity" (Chomsky 1992).

Research in the theory of morphology (which plays a central role in the minimalist theory) and phonology ranges from work on quite language-specific topics (e.g. Indo-European phonology; Spanish and Catalan morphology) to the very general (e.g. on distributed morphology, on the free Element Condition in phonology, and on the philosophical foundations of phonology and morphology).

RESEARCH: PHILOSOPHY

There are a number of topics being pursued in current research in philosophy, including the following: associative democracy, consciousness, Frege's conception of logic, Hegel's social philosophy, interrogatives, the logic of provability, logical omniscience, moral conflict and moral dilemma, natural kinds, and the nature of happiness.

PUBLICATIONS

As in the past, the faculty of both sides of the department published a large number of chapters in books, journal articles and reviews. In addition, a collection of Professor Sylvain Bromberger's essays, *On What We Know We Don't Know*, was published jointly by the University of Chicago Press and the Stanford University Center for the Study of Language and Information. The MIT Working Papers in Linguistics launched its new Occasional Papers in Linguistics series with the publication of Institute Professor Noam Chomsky's *A Minimalist Program for Linguistic Theory*. Professor Michael Kenstowicz, together with P. Bertinetto and M. Loporcaro, edited *Certamen Phonologicum II: Proceedings of the Second Cortona Phonology Conference*. Professor Irving Singer's latest book, *Meaning in Life: The Creation of Value*, was published in the spring by the Free Press.

HONORS AND AWARDS

Professor Judith Thomson was named Laurance S. Rockefeller Professor of Philosophy, and Associate Professor Irene Heim the Class of 1943 Career Development Professor.

On 8 April Professor Chomsky delivered the James R. Killian Faculty Achievement Award Lecture "Language and the 'Cognitive Revolutions'" to a full house in Kresge Auditorium. He was awarded

honorary degrees by Gettysburg College and the University of Maine. Institute Professor Morris Halle received an honorary degree from the University of Chicago at its centennial commencement ceremonies.

Professor Kenneth Hale is President-elect of the Linguistic Society of America. Professor George Boolos served as Vice President of the Association for Symbolic Logic; both he and Professor Robert Stalnaker were elected Fellows of the American Academy of Arts and Sciences.

LEAVES OF ABSENCE

With the support of a two-year research grant from the National Science Foundation, Professor Hale continued his work on the syntax and semantics of ergativity in language during his fall-term sabbatical. He was also a central participant in the Fifth Brazilian National Seminar on Recent Developments in Generative Grammar held in Brasilia in October-November 1991.

Professor Paul Horwich spent his spring-term sabbatical at the Center for Research in Applied Epistemology in Paris.

PERSONNEL

We note with pleasure Irene Heim's promotion to tenure at the rank of Associate Professor, and the promotion of Michael Hardimon and Paul Hoffman to the rank of untenured Associate Professor, effective 1 July 1992. Professor Hoffman has since resigned from MIT in order to accept a faculty position at the University of California at Riverside. After nearly twenty years of work in the Linguistics office, Ms Nancy Peters has retired from her support staff position.

The Department's major affirmative action goal, to increase the representation of women on the faculty to at least three from the present two, remains to be met. There have been no additions to the faculty during the present academic year. The Department is, however, poised to take advantage of the Provost's women's faculty initiative. The more distant goal, that of increasing the number of faculty from underrepresented minority groups from its current and dismal level of one, continues to elude us.

There have been no new additions to the support staff, so there is no progress to report on meeting affirmative action goals in this personnel category either. With the retirement of Ms Peters, however, there is some possibility for change there.

WAYNE O'NEIL

Department of Political Science

Three years after the fall of the Berlin Wall, the challenges of analyzing and contributing to a rapidly changing world order have become the foremost puzzles for teaching and research in the Department of Political Science. Some of the issues that faculty are addressing are essentially new ones; for example, the research of Professor Stephen Meyer on the distintegration of Soviet military forces, or the work of Assistant Professor Stephen Van Evera on American foreign policy after the Cold War. Some of the issues are newly salient for politics as, for example, the concerns with global climate and environment which have been discussed this year in a faculty seminar chaired by Professor Nazli Choucri, and which are addressed in new research projects of several of the faculty ranging from Professors Eugene B. Skolnikoff and George Rathjens who focus on technology and politics, to Professor Joshua Cohen who is concerned with the impact of decisionmaking in environmental areas on social justice, intergenerational equity, and participation. But even for those faculty whose research agenda has not apparently shifted, the effects of the transformation of the international system are massive. Thus Professor Charles Sabel, for example, whose work has long focussed on questions about the restructuring of industrial economies in the United States and West Europe, is now engaged in collaborative research with German scholars on the reconstruction of East German industry. Professor Myron Weiner, long a scholar of migration and politics in the Indian subcontinent, now is shifting to examine the political implications of the migratory flows set into motion by the collapse of the Soviet empire, and will head up a project for the American Academy of Arts and Sciences on the moral implications of international population movements. There are many challenges for the Department as we move to these new problems: how to incorporate these new concerns into the curriculum; how to assist our graduate students with research in new areas in which the faculty are, as much as those whom they supervise, confronting largely unknown territory; how to provide resources to faculty seeking to shift from old specializations to new problems; among others. These problems will be our agenda for the near future. The Department will move forward on these issues under a new Head, Professor Richard J. Samuels, who will replace the current Head, Professor Suzanne Berger, as of September 1992.

The Department continues to devote its major collective efforts to recruitment and new faculty. This year we succeeded in hiring Associate Professor James Snyder, a social scientist whose contributions to formal modelling and methodology are widely admired within both political science and economics. He has worked on issues of campaign finance, the influence of interest groups in Congress, and currently in analyzing the disparity between preferences of Members of Congress and those of the electorate. This appointment marks a first success in an eight-year long effort to build strength in the field of methodology. The promotion to tenure of Associate Professor Charles Stewart III this year contributes to rebuilding the field of American politics in the Department and also strengthens the methodology field.

Unfortunately we were unsuccessful with our offers to four junior scholars whom we hoped would join us in the American politics and methodology fields. This disappointment was all the more regrettable

since three of the four were women, one of whom was an African-American, and the fourth was a Hispanic-American. We remain committed as a Department to hiring more minority faculty, since the underrepresentation of minorities and women in the faculty is a real loss for our students. The new graduate student administrator, Ms. Jeanne Washington, is an African-American. Dr. Kenneth Williams, an African-American political scientist from Michigan State University, spent this year in the Department as a post-doctoral fellow. In order to identify outstanding minority scholars, we have intensified our search procedures. In addition to wide advertisement of our designated hiring slots and to advertising our willingness to consider hiring minorities in any political field, the Department Head also writes personally to each member of the African-American and Latino caucuses of the American Political Science Association. This year and next Professor James Jennings, a Black Puerto Rican political scientist, is replacing Professor Michael Lipsky currently on leave at the Ford Foundation to head up their efforts on democracy and governance. Ms. Margaret Burnham, an African-American attorney and former Boston Municipal Court judge, continues to teach in the Department; she delivered the major address at the Institute's commemoration of Martin Luther King's birthday.

The Department's teaching is evolving in order to incorporate new issues. Thus Professor Donald Blackmer has developed a new subject, Communist Politics After Stalin, as well as a new junior colloquium for political science majors. Professor Meyer, in a major departure from his previous research and teaching in the Soviet and defense fields, is preparing a new undergraduate subject, Environmental Politics and Policy. Associate Professor Kenneth A. Oye taught two new subjects on American foreign policy last fall. Professor Rathjens has prepared a new subject on energy. To address interest in the elections, Professor Stewart offered an undergraduate seminar that offered the opportunity for students to work in campaigns and combine practical experiences with reading, lectures, and a group project.

The scholarly contributions of the faculty continue to be strong. A list of recent monographs and articles would be too long to reproduce here, so we note only recent books and those that will appear before the end of 1992, even though this misses the work of faculty whose research is usually reported in journal articles. Professor Oye's Economic Discrimination and Political Exchange: World Political Economy in the 1930s and 1980s (Princeton University Press) appears this summer. Associate Professor Jonathan Fox's The Political Dynamics of Reform: State Power and Food Policy in Mexico (Cornell University Press) will appear this fall, as will Associate Professor Ellen Immergut's Health Politics: Interests and Institutions in Western Europe (Cambridge University Press) and Associate Professor Uday Mehta's The Anxiety of Freedom (Cornell University Press). Professor Choucri, together with co-authors Robert North and Susumu Yamakage, are bringing out The Challenge of Japan before World War II and After (Routledge), and she also has in press an edited volume, Global Accord: Environmental Challenges and International Responses (MIT Press). Professor Lucian W. Pye published Chinese Negotiating Style: Commercial Approaches and Cultural Principles (Quorum Books) this year, as well as a new edition of his Spirit of Chinese Politics. Professor Skolkinoff's new book, The Elusive Transformation: Science and Technology and the Evolution of International Politics, is

forthcoming from Princeton University Press. Professor Weiner together with Professor Samuels edited and contributed to a volume in honor of Professor Pye, The Political Culture of Foreign Area and International Studies (Brassey's). This volume was formally presented to Professor Pye at a May 10 dinner marking his retirement from MIT. Among the world's foremost scholars of Asian politics, Professor Pye has also been a leader in the social sciences in the integration of psychological theory into political analysis. He served as President of the American Political Science Association.

Faculty received honors and numerous grants this year. Professor Willard Johnson was named an African-American Man of Vision by the Museum of African-American History, Boston. Professor Fox was invited to present an inaugural address to the First Trinational Exchange on Agriculture and the Environment in Mexico City last fall. He has also received funds from the World Bank for a study of community participation in Mexico. Professor Sabel has received funds from the DAAD and the Harvard Center for European Studies for research on East German industry. Professor Suzanne Berger and Adjunct Professor Ronald Dore have received funds from the MIT Industrial Performance Center and the Rockefeller Foundation for research and a conference on the impact of trade on domestic production structures. Professor Meyer received grants for research changes in the Soviet military and in Soviet defense industries from the National Council for Soviet and East European Research and from the Office of Net Assessment. Professor Harvey Sapolsky received major funding from the Carnegie Corporation for the Defense and Arms Control Studies (DACS) Program.

MIT political scientists continue active in professional associations and journals. Professor Hayward Alker serves as President of the International Studies Association and President of the Institute for Defense and Disarmament Studies, as well as on the Executive Committee of the International Social Sciences Association. Professor Pye is Vice Chairman of the National Committee on US-China Relations and a trustee of the Asia Foundation. Professor Sapolsky chairs the Woodrow Wilson Prize Committee of the American Political Science Association. Professor Berger is a member of the Executive Committee of the Social Science Research Council.

Within the Institute, political science faculty are active in various ways, from serving on standing committees of the faculty to new Institute-wide initiatives. Professor Sapolsky chairs the Faculty-Administration Committee and organizes the Communication Forum. Professor Alker serves on the Institute Committee on Admissions Policy and Financial Aid. Professor Choucri serves on the MIT Council on Global Environment, the Committee on Privacy, and heads the Middle East Program. She also organizes and heads the MIT Faculty Seminar on Global Change, and is editing a new MIT Press series on Global Environmental Accords. Professor Oye is headmaster of East Campus. He initiated a survey on sexual, ethnic, and racial harassment at MIT and has taken a leading role in campus discussions of these problems. Professor Oye becomes Director of the Center for International Studies this July, replacing Professor Weiner, who served as Director for the past five years. Professors Blackmer and Cohen have been serving on HASS committees this year. Professor Johnson served on the Corporate Joint Advisory Committee and the Technology and Culture Seminar Steering Committee.

Outside the Institute, faculty contribute to analysis and policy in various ways. Professor Choucri has been an active participant in many facets of the UNCED pre-Rio process, and also collaborated in the team headed by Professor Weiner that worked on Afghan reconstruction under USAID aegis. She has been a major speaker at the Joint Meeting of the US Council for Energy Awareness and the US Energy Forum. Professor Cohen has taken the lead in a local journal of critical and cultural studies, The Boston Review, which in its new format is stirring new debates over issues of interest to a wide educated audience. Professor Johnson has been involved in creating a new Foundation for Africa to be directed and staffed by Africans resident in the US. Professor Skolnikoff has been involved with an effort to help Russian science through the American Academy of Arts and Sciences. Professor Immergut was appointed to the US Congress' Office of Technology Assessment Panel on International Health Care Expenditures. Professor Fox advises several programs on grassroots democracy in developing countries. Professor Rathjens continues to be active in Pugwash conferences and in the Council for a Livable World. Professor Meyer has been testifying before Congressional committees and involved as a senior review panel member for the Office of Technology Assessment, the Central Intelligence Agency, and the Government Accounting Office. Professor Berger continues to direct Seminar XXI: Foreign Politics and the National Interest, a seminar held in Washington every month for 55 members of the national security community from government, the military, and industry. Professor Weiner has organized for the Foreign Service Institute several workshops on international affairs.

SUZANNE BERGER

Program in Science, Technology, and Society

The 1991–92 academic year was one of the busiest and most satisfying in the Program in Science, Technology, and Society's (STS) sixteen-year history.

DOCTORAL PROGRAM

In its fourth year, the Doctoral Program in the History and Social Study of Science and Technology (a collaborative venture of STS, the History Faculty, and the Anthropology/Archeology Program) continued to develop in a satisfactory way. Present and incoming students received a variety of grants, including Mellon, National Science Foundation (NSF), Lyons, Ida Green, and MacArthur Fellowships. The Program had sixty applicants this year, of whom a dozen were considered exceptionally well qualified by the Admissions Committee. Four of the five students offered admission decided to come to MIT. The Committee on Graduate Studies and Programs reviewed the Doctoral Program and approved its development to date. Important roles in the Doctoral Program were played by Professors Merritt Roe Smith (Director of Graduate Studies) and Sherry Turkle, both of STS, Professor James Howe of the Anthropology/Archeology Program, and Associate Professor Peter Perdue of the History Faculty, all of whom were members of the Doctoral Program Steering Committee.

PROJECTS, GRANTS, AND INITIATIVES

The STS Program received $1.831 million in grants for new research projects.

Integrating the American Past: A New Narrative History of the United States

The Alfred P. Sloan Foundation approved a grant of $1.281 million for a five-year project aimed at producing a multi-volume narrative history of the United States that addresses processes of technological and scientific change and places them at the core rather than the periphery of the American experience. The resulting study is intended both for the general public as well as introductory college courses in American history. The project is initiated and directed by Professor Smith and will include Professors Pauline Maier (MIT), Alex Keyssar (MIT), and Daniel Kevles (California Institute of Technology) as primary collaborators.

Humanities and the Environment

Based on an Officer's Grant from the MacArthur Foundation, Professor Emeritus Leo Marx organized a series of nine workshops held at MIT on the theme of "Humanistic Perspectives on Atmospheric Change." Based on the success of these preliminary workshops, Emeritus Professor Marx, Professor Kenneth Keniston, and Visiting Professor Jill Conway succeeded in raising $500,000 from the MacArthur Foundation for a three-year project on "Humanistic Studies of the Environment." The project will consist of workshops, seminars, graduate fellowships, and visiting scholars, with work to commence in the fall of 1992. The newly-funded project will be headed by Professors Keniston, Marx, and Conway.

Science-Government Workshops

A series of nine faculty workshops on "The Relationship of University Science and the Federal Government" were held at MIT during the academic year. Funded by the Carnegie Foundation and by MIT, the speakers examined changes and tensions in the alliance between research universities and the Federal government. It is expected that the results of the workshop will be published.

Study of the Life Sciences

The second year of the Mellon Project focused on "International Perspectives on Genetics and Biotechnology: The Rise of Modern Biology, c. 1920s–1960s," and was headed by Assistant Professor Lily Kay of MIT and Professor Everett Mendelsohn of Harvard. In addition to a well-attended spring workshop on the year's theme, the project also resulted in two new related seminars taught in AY91–92: "Biology and Society in Modern America" (Professor Kay) and "Biotechnology and Society" (Professor Charles Weiner). An international field of twenty-three candidates applied for the three available fellowship positions. Those appointed are Dr. Richard Doyle (University of California, Berkeley), Dr. Michael Fortun (Harvard University), and Dr. Herbert Gottweis (University of Salzburg, Austria). Professor Weiner will assume leadership of next year's workshop on the international aspects and cultural and political significance of genetic engineering and biotechnology.

US-Soviet Science Workshops

Funded by the MacArthur Foundation, this project is in its second year and is headed by Professor Loren Graham.

Two workshops were held this year: one in Moscow in October 1991 on "The Social, Political, and Cultural Dimensions of the Environmental Crisis in the U.S. and U.S.S.R." and one at MIT in May 1992 on "Science and Political Authority." Given the dissolution of the Soviet Union and the current crises in former Soviet countries, these workshops proved particularly pertinent and attracted sizeable audiences.

New Faculty Appointments

We are very pleased to report that, owing to MIT's Affirmative Action Program, STS has been very successful this year in recruiting women and underrepresented minorities to our faculty. Joining us next year are Professor Evelyn Fox Keller (Professor of the History and Philosophy of Science) from the University of California, Berkeley, and Assistant Professor Evelynn Hammonds (Assistant Professor of the History of Science) from Harvard University. Professor Keller is internationally known for her path breaking contributions to the study of gender and science as well as the history of biology and is a recent recipient of a MacArthur Prize Award. Professor Hammonds specializes in the history of public health as well as African-American history and 10th and 20th century women's history; she comes to us with very high recommendations from her graduate mentors. In addition to these appointments, the STS Program concluded two additional appointments this year: Professor Jed Buchwald (Bern Dibner Professor of the History of Science and Technology, joint with History) and Assistant Professor Hugh Gusterson, Assistant Professor of Anthropology and Science Studies, joint with Anthropology/Archaeology). A fifth appointment is in the final stages of negotiation and should be concluded shortly. He is Professor Michael Fischer (Professor of Anthropology and Science Studies). These appointments greatly strengthen the social study component of the Doctoral Program in the History and Social Study of Science and Technology and solidifies its growing reputation as the strongest in the world.

The Dibner Institute for the History of Science and Technology

Professor Smith has served as Interim Co-Director of the Dibner Institute and as a member of the search committee for both the Dibner Professor and the Librarian of the Burndy Library. With the conclusion of the final agreement between MIT and the Dibner Fund, planning for a series of workshops on problems of pure and applied science and on the European roots of the American system of manufacturing is well under way. The first of several graduate students has been nominated for a Dibner Dissertation Fellowship in the history of science. Generally the new Dibner Professor (Jed Buchwald) and the Director of STS have been working closely together in forging close ties between their respective programs.

SPECIAL EVENTS

1992 Arthur Miller Lecture on Science and Ethics

The third annual Arthur Miller Lecture occurred on April 29 and involved a panel discussion on "The Crisis in Russian Science: What is to be Done?" Speakers included Professor Graham, Provost and Institute Professor Emeritus Walter Rosenblith, Dr. Dmitry Piskunov (National Academy of Sciences of Russia), and Dr. Nikolai Vorontsov (Chief Scientist, The Kol'tsov Institute of Evolutionary Biology and National Academy of Sciences of Russia). Moderated by Institute Professor Emeritus Victor Weisskopf, the lecture was attended by more than seventy people. Afterwards the lively discussion continued at a dinner attended by the panelists and members of the Miller family.

1991 Siegel Prize in Science, Technology, and Society

Awarded for the best student paper on the historical, social and policy implications of science and technology, two co-winners were chosen from a field of eleven papers. The winning papers "Science, Security, and the Cold War" by Ms. Jessica Wang and "The Politics of Expertise in Congress" by Mr. Bruce Bimber have been produced as part of the *STS Working Papers* series. Applications for the second year of the award have been received; the winner of the Prize will be announced in the fall.

EDUCATIONAL ACTIVITIES

The STS Program's educational work continued at both the undergraduate and the graduate levels. In all, the Program offered 20 undergraduate subjects and 31 graduate subjects during the past academic year. Undergraduate enrollments were 380. STS offered two new undergraduate courses, "The Civil War and Reconstruction" by Professor Smith and "Science and Religion in 20th Century Society" by Visiting Professor Marc Swetlitz.

On the graduate level, several new seminars were introduced. They include: "Research Strategies and Designs" taught by Professors Deborah Fitzgerald and Keniston; "Knowledge in Context" taught by Professor Turkle; "Technology and Management in the Era of the Industrial Revolution" taught by Professor Smith; "American Political and Social History in the Late 19th and 20th Centuries" taught by Professor Keyssar; "Science and Technology in International Affairs" and "Public Policy and Climate Change," both taught by Professor Eugene Skolnikoff.

COLLOQUIA

The STS Colloquium has become a core activity of the Doctoral Program in the History and Social Study of Science and Technology. In its second year and headed by Assistant Professor Fitzgerald, the Colloquium brought eighteen speakers to MIT from such institutions as Cornell University, Rutgers University, University of Pennsylvania, and University of Michigan. The Colloquium will continue next year under the leadership of Professor Keller.

CONTINUING ACTIVITIES

The Program continued a number of activities that had been initiated in earlier years. In the Student Lunch Workshops graduate students meet bi-weekly to discuss their ongoing research and current literature in the history and social study of science and technology. The *STS Newsletter*, ably produced by staff member Mr. Graham Ramsay, continued with articles of general interest followed by news and notes on STS faculty, staff, and students. The STS Working Papers, under the editorship of Professor Keniston, continue to provide a means of disseminating early versions of work in progress.

KNIGHT SCIENCE JOURNALISM FELLOWSHIP PROGRAM

In its eighth year, the Knight Program continues to attract science journalists from around the world to MIT to learn more about the technical subjects about which they write and to attend seminars, classes, and workshops devoted to science and technology studies. This year's group included twelve Fellows from the United States, Germany, and Poland. Fourteen new Fellows were selected from a pool of 38 applicants that increased from 32 to 38 this year and included the Program's first fellow from Australia. Thanks to the collaboration of Senior Research Associate Victor McElheny (Director of the Knight Science Journalism Fellowship Program), Professor Keniston, and graduate student Mr. Wade Roush, the Knight Program and STS established a successful joint seminar and continue to be closely linked despite the greater geographic distance between the two related enterprises.

FACULTY ACTIVITIES

Associate Professor Louis Bucciarelli serves as Director of Program Development for Project ECSEL, funded by NSF. He also is Co-Director of MIT's Integrated Studies Program and a member of the MIT Council on Primary and Secondary Education. Professor Fitzgerald was promoted to associate professor without tenure. In addition to her ongoing research on the corporatization of American agriculture, she served on The MIT Press editorial board and chaired the Program Committee for the 1992 annual meeting of the Society for the History of Technology in Uppsala, Sweden. She also presented invited papers at the 3rd Annual Congress for the History of Latin American Science and Technology in Mexico City and at the Rockefeller Foundation-sponsored meeting on "Ethical Perspectives on Agricultural Research" in Bellagio, Italy, and is editing a book series on Rural America for The Johns Hopkins University Press. Professor Graham headed the MacArthur-funded project on the Social and Political Dimensions of Science and Technology in the U.S. and U.S.S.R. Among his publications are "The Fits and Starts of Russian and Soviet Technology," in J. P. Scanlon, *Technology, Culture, and Development* and "The Spectre of Whig History" in S. Jasanoff, *The Outlook for STS* and a review of *The Memoirs of Zara Witkin* in *The New York Times Book Review*. He also was honored as "Distinguished Lecturer" by the History of Science Society. Assistant Professor Kay published "The Politics of Fame: The Protein Network and the Tiselius Apparatus," in *Centre at the Periphery: Swedish Science in the Twentieth Century* and delivered invited lectures at Stanford University, the University of Erlangen (Germany), and the University of Geneva (Switzerland). During the spring of 1992 she was a Visiting Scholar at the Max Planck Institut fur Biophysicalische-Chemie at Gottingen, Germany. Professor Keniston published "What is the Outlook for STS" in *The Outlook for STS* and received a $500,000 grant from the MacArthur Foundation for Humanistic Studies of the Environment. He also was appointed to the Guggenheim Foundation's Committee of Selection.

Senior Research Associate Victor McElheny directed the Knight Science Journalism Fellowship Program and received a $100,000 grant from the Sloan Foundation to complete a biography of Edwin H. Land. Among Professor Theodore Postol's publications are "Lessons of the Gulf War Experience with Patriot" in *International Security* and "SLCMs - Ignored, then Stored" in *Bulletin of the Atomic Scientists*. He also served on the editorial boards of *International Security*, *Science and Global Security*, and *PSR Quarterly* and delivered lectures at Harvard University, Stanford

University, and the Fermi National Accelerator Laboratory. Professor Smith served as Acting Director of the STS Program and as Acting Co-Director of the Dibner Institute for the History of Science and Technology. He received a grant from the grant from the Sloan Foundation to prepare a general survey of American history and lectured at Connecticut College, Cornell University, and Yale University. Professor Leon Trilling continued to contribute to Project ECSEL and published "Engineering Education: An International Perspective" in *Proceedings of the 7th IEEE Careers Conference*. He also served as a member of the STS Program Visiting Committee at Vassar College. Professor Turkle was elected a Fellow of the American Association for the Advancement of Science and gave invited lectures at Cornell University, Tokai University (Japan), the Society for Social Studies of Science, the Massachusetts Corporation for Educational Telecommunications, and the National Psychological Association for Psychoanalysis. Her publications include "Epistemological Pluralism and the Revaluation of the Concrete" in *Journal of Mathematical Behavior*, "Paradoxical Reactions and Powerful Ideas: Educational Computing in a Department of Physics" in E. Barrett, *Sociomedia, Hypermedia, and the Social Construction of Knowledge*, and "Psychoanalytic Culture" in H. Morris, *Telling Facts: History and Narration in Psychoanalysis*. Professor Weiner delivered invited lectures at the University of the Americas (Mexico), The Science Museum (London), and the New York Academy of Sciences. He served on an advisory committee to the Project on State Governments and the Human Genome Initiative and is a member of the Advisory Committee on National Museum of American History's (Smithsonian) exhibit on "Science in American Life."

MERRITT ROE SMITH

Center for International Studies

Overview

In this fifth year of the Center's directorship under Professor Myron Weiner, its four major programs - the Defense and Arms Control Studies Program, the Japan Program, the Program in Development Studies, and Seminar XII: Foreign Politics and the National Interest - all have attempted to respond to the rapidly changing events in the international arena. A major concern during 1991-92 has been to insure a smooth transition, in terms of both program development and funding, for the new CIS Director, Associate Professor Kenneth Oye, who will assume the directorship July 1, 1992.

Defense and Arms Control Studies Program

The world's security arrangements continued in flux as attempts were made to cope with an amazing series of events: The collapse of the Soviet empire, the end of the Cold War, and, most recently, the disintegration of the Soviet Union and the destruction of the Communist Party nearly everywhere as a major political force. The Defense and Arms Control Studies Program (DACS) has sought to analyze the security alternatives available to the United States and other major and regional powers. Of great interest to the program was the role that emerging economic and environmental problems are likely to have in affecting international security arrangements, military options, and the resources made available for armed forces.

To explore relevant issues, the program sponsors a number of working groups which are research collaborations of faculty, staff and students, with each group adopting a distinctive format. One led by Professor Harvey Sapolsky examines American defense policies and has been especially concerned with the effect casualties have on the conduct and political acceptability of war. Another directed by Professor Stephen Meyer has focused on the security policies of the former Soviet Union and most recently on the adjustments made by the defense industries of the former Soviet Union to new political and economic realities. A third led by Professor Barry Posen has concentrated on conventional warfare issues with special emphasis on armored forces. A fourth led jointly by Professor Leon Trilling of the MIT Aeronautics and Astronautics Department and Professor Sapolsky has been concerned with the post-Cold War future of the world's aerospace industry. A fifth directed by Professor Theodore Postol explores defense technology issues, most recently the effectiveness of the Patriot missile system in the Gulf War. A sixth also led by Professor Sapolsky has been examining the environmental legacies of the Cold War. And a seventh, jointly directed by Professors George Rathjens and Jack Ruina, has been exploring American national strategy and force requirements in a world without a Soviet Union. In addition, the Program sponsors several seminar series including the DACS seminars, the Technology and Arms Control seminars, and the Defense Science seminars.

The director of the program is Professor Sapolsky, who has sought to encourage the initiatives mentioned above and to increase the Program's research and public activities. Among the publications are *Breakthroughs*, a new program journal now in its third year; *DACS Facts*, the Program's newsletter; and *Soviet Defense Notes*, the product of the Soviet Security Studies Working Group led by Professor Meyer. A working paper series has also been restarted. A closer affiliation has been created with Dr. Marvin Miller's long-standing research project on nuclear proliferation and with a newer one that Professor Emeritus Carl Kaysen is building on international security norms. The program also formed ties with several local and national defense firms and laboratories to explore topics of mutual interest. Its major sponsors have been the Carnegie, Hewlett, Ford, Sloan, Pew and MacArthur Foundations. Over 35 graduate students are affiliated with the Program. Four visitors were with the Program during the year.

Program in Development Studies

Research on developing countries has been a major focus of CIS throughout its forty year history. However, unlike the other major areas of concern at the Center, there has never been a formal institutional framework for development studies within the Center. Such a framework was created during 1991-92 by establishing a Development Council, with its own planning committee responsible for overseeing existing programs and generating new activities. Workshops and seminars, interdisciplinary research and individual scholarly efforts focus on five thematic areas: new and resurgent nationalisms, international migration and refugee flows, poverty alleviation in developing countries, global environmental change, and post-war reconstruction in the Middle East. Within that framework, the following seminars and workshops have had a lively following during the past year: the newest seminar, The Political Uses of History, organized by Professor Hayward Alker (Political Science) examined the social construction of history, nationalism in historical education, and the uses of history to create national identity; a related seminar, Peoples and States: Ethnic Identity and Struggle, chaired by Professor Jean Jackson (Anthropology/Archaeology), examined the relationship between ethnicity, ethnic identity and struggle; the Seminar on Institutional Perspectives on Third World Development, organized by Professor Bish Sanyal (Urban Planning), Associate Professor Jonathan Fox (Political Science), and Professor Lance Taylor (Economics), continued to focus 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), in its 28th year, focused on the effects of war on development; the Bustani Middle East

Seminar, organized by Professor Philip Khoury (History) dealt this year with such themes as Iraq after the Gulf War and women in the Middle East; the MacArthur Graduate Student Seminar, organized by Dr. Elizabeth Leeds (CIS) brought together graduate students with MacArthur grants from the departments of Political Science, Economics, Urban Studies and the School of Management to report on research in progress. Under the general theme of environmental issues, the inter-disciplinary Faculty Seminar on Global Environmental Change brought together faculty from the social sciences, engineering and the environmental sciences to discuss such issues as new energy options, global warming, environmental research and the role of the United Nations in environmental cooperation. A related new seminar, the Political Economy of World Energy Markets, began in the spring. Both seminars are organized by Professor Nazli Choucri (Political Science). Finally, another new seminar on Social Movements, coordinated by Associate Professor Uday Mehta (Political Science), provided a lively forum for discussion of recent theoretical trends in social movement research.

The Center also sponsored two major conferences during the year. The first, on the Impact of International Migration on the Security and Stability of States, organized by Professor Myron Weiner and held in December, 1991, focused on state policies toward migration that are shaped by concerns of internal stability and international security. It was founded by the Sloan Foundation. The second, on Central and Southwest Asian Republics of the Former Soviet Union, dealt with the historic ties, emerging relations and alternative futures of the republics. The two-part Conference, held in March and May, 1992, was supported by the Fund for Peace.

Japan Program

Last autumn, the Air Force Office of Scientific Research (AFOSR) named the MIT Japan Program as the recipient of one of its four United States-Japan Industry and Technology Training Program grants. With major funding received from this grant and with support from its past grantors, the year to date has been one of extraordinary growth for the Program in all three of its core activities, namely education, research and public awareness.

Intern placement continues to be the primary focus of the Program's educational activities. During academic 1991-92, the Program placed 46 interns in Japanese institutions. The Program is continuing to expand its educational materials on Japan. The case studies used in the training of MIT Japan Program interns are the material for a just-completed book by Program Managing Director Patricia Gercik, *On Track with the Japanese: A Case-by-Case Approach to Building Successful Relationships*, which will be published by Kodansha Press International this autumn. One of the cases is currently being made into a CD-ROM video for further training. The Program's eight-week intensive course in Technical Japanese for computer scientists and electrical engineers is now in its fifth summer. Based on the success of this course, the Program has, this summer, inaugurated a concomitant course in Technical Japanese for Materials Scientists and Engineers. During the past year, in accordance with its mandate to educate Americans about Japan, the Program has hosted a number of new government and academic communities. Last autumn, for example, the Program hosted an intellectual property seminar. In May, the Program followed up with a two-day seminar entitled "Japan Aware; Japan Prepare: Effectiveness Training for Scientists, Engineers and Managers." The goal was to present an introduction to the basic skills and information necessary for successful interactions with Japan in the arena of science and technology. This year, for the first time since its establishment, the Program is also sponsoring a nine-week summer program course in Japan Effectiveness Training for Scientists, Engineers and Managers that combines intensive first-year Japanese with a series of seminars that examine the ramifications of a series of topics for productive interaction with Japan. Finally, the Program has initiated a major ongoing project in the field of education, its Japan Target Seminars for technologically sophisticated professionals in business and government on specific topics such as manufacturing in Japan and R&D in Japan.

In the area of research, the Program has added a Washington, DC based research associate, Michael Green, who has just published a working paper entitled *Boeizoku: Defense Policy Formation in Japan's Liberal Democratic Party*. In June, the Program hosted a research-based workshop on US-Japan Defense Technology collaboration. The purpose of the event was to examine several areas of defense technology cooperation, including industry-to-industry joint development, critical technologies, government-to-government collaboration, and flow back from license production. Papers were presented on each of these issues and working groups to discuss them over the coming year are being formed. This will provide the basis for a larger conference in the Spring of 1993. In addition, Program Director Richard Samuels has spent the last year in Japan on a Fulbright post-doctoral award and has completed the research for his upcoming book (Cornell University Press) to be entitled *Rich Nation, Strong Army and Japanese Technology*. Earlier this year he published, with co-author David B. Friedman, a highly acclaimed Program working paper, *How to succeed Without Really Flying: The Japanese Aircraft Industry and Japan's Technology Ideology*. Finally, Program associate Jim Womack, author of *The Machine That Changed the World* is doing Program-sponsored research on government and industrial organization in the US and Japan.

In the area of public awareness, the past year has seen the establishment of two major new initiatives. 1) *US-Japan Science and Technology Newsletter:* This newsletter, to be published ten times a year, will use primary source material to provide information and analysis concerning science and technology in Japan and their impact on current relations between the US and Japan. The audience for the newsletter will be US business, government, and research institutions, including universities; and 2) Japan Databases: The Program has hired a full-time staff person to create databases on Japan-aware professionals,

including MIT Japan Program interns, in specific areas of interest; experts in what Japan is doing in specific areas of science and technology; and Japan trip reports from MIT faculty members. The Program continues to host a series of small seminars aimed at its corporate sponsors, and Trilateral Forum Dinners, which are invitation-only dinners to bring together leaders in Japanese and US industry, government and academia with the goal of enhancing dialogue between the two countries. These are supplemented by the Program's Technology Forum Lecture Series and on-campus cultural activities, including film showings, a weekly Japanese lunch table and specila IAP events.

The Program now has 17 corporate sponsors and continues to enjoy the generosity of its Japanese host companies, the AFOSR, the Center for Global Partnership, the Japan Foundation, the Japan-US Friendship Commission, the National Science Foundation, the Starr Foundation, and, for the technical Japanese courses, NEC and Toshiba.

Seminar XXI

Seminar XXI is an educational program run in Washington, DC for senior military officers, government officials and industry executives in the national security policy community. Conducted under the auspices of CIS and under the direction of Professor Suzanne Berger (Political Science), Seminar XXI recently completed its sixth year and continues to enjoy great success.

The main objective of Seminar XXI is to develop among the program fellows new analytic skills for understanding foreign societies, including the instincts to ask different questions about the facts they receive on the job and in turn, to search out alternative interpretations of that data. Seminar XXI met eight times over the course of the year, with each session focusing on a different foreign country or issue. The approach is not meant to cultivate country or functional expertise, but rather, to provide concrete examples of the program's essential point: that different frames of interpretation through which societies are understood yield fundamentally different answers to the questions these policy makers must ask and resolve. By considering the politics of each country through different frameworks of analysis, the range of possible explanations for the behavior of a set of countries important to the US is widened, as is the range of US policy options which can be considered systematically.

Each of the eight sessions brought together distinguished faculty from US and foreign institutions

Fellowships

CIS sponsors annually four fellowship competitions for graduate students and faculty. (1) In the second-phase of a three-year grant from the US Department of Education, Institute for International Education, the Center has awarded four academic year and five summer grants under the Foreign Language and Area Studies (FLAS) Fellowship Program. Languages being studied are Japanese, Russian, Hungarian, Khmer, and Portuguese. (2) Under a grant from the John D. and Catherine T. MacArthur Foundation, Program in Peace and International Cooperation, the Center provides funds to doctoral students in the social sciences engaged in innovative research on international peace and cooperation, security, and development. During 1991-92, CIS awarded fourteen MacArthur Fellowships to students from the Departments of Political Science, Urban Studies and Planning, the Sloan School of Management, and the Program in Science, Technology and Society. (3) As a participant in the Social Science Research Council International Predissertation Fellowship Program, MIT doctoral students in the social sciences are invited to compete for fellowships providing twelve-month support for supplementary training in developing areas. In the 1992 competition MIT was the only institution out of twenty–three participating to have a 100% success rate with five grantees. (4) The International Energy Policy Research Grant competition is open annually to faculty, researchers, and doctoral students. Seven awards were given to students and faculty from the Departments of Political Science, Urban Studies and Planning, Nuclear Engineering and the Sloan School of Management.

Other Activities

During 1991-92 CIS was host to visiting scholars from Brazil, Mexico, Israel, India, Japan, Korea and Russia as well as to American scholars working on such subjects as the role of media simulations in international relations, the politics of social welfare development in Brazil, women's changing roles in rural development, the changing political culture of Francophone Africa, rural social movements in Brazil, and nuclear proliferation in the Middle East. In addition to the publications of the DACS and Japan Programs, the Center publishes Precis, a bi-annual newsletter, and two working paper series: CIS Working Papers and Findings, a series of article-length summaries of recently completed social science dissertations in comparative and international studies. The latter is funded by a grant from MIT alumnus Robert Wilhelm.

ELIZABETH LEEDS

Center for Materials Research in Archaeology and Ethnology

The focus of the Center for Materials Research in Archaeology and Ethnology (CMRAE) this year was archaeological ceramics, both in our teaching and our research. The year-long graduate subject, Materials in Ancient Societies: Ceramics, was taught by faculty from MIT and Harvard University; our students were from MIT, Harvard, Boston University, and Tufts University. This subject presented a rare combination of materials science, geology, and archaeology, carefully integrated in laboratories and seminars around the theme of ceramics: as evidence for the reconstruction of ancient technologies and for the interpretation of cultural form. Assistant Professor Dorothy Hosler, Dr. Maria Masucci, who joined CMRAE as Post-Doctoral Associate, and three MIT UROP students worked together as a research team in an ongoing project to investigate ceramic production technologies of prehistoric Ecuador. This research represents the first comprehensive technical study of Ecuadorian ceramics and is particularly important because the ceramic tradition of Ecuador is the earliest anywhere in the New World.

The academic year opened for Professor Hosler (Anthropology/Archaeology Program and CMRAE) with the award of an Esther and Harold E. Edgerton Career Development Professorship. While finishing her book manuscript *The Sounds and Colors of Power in Ancient West Mexico*, on contract with the MIT Press, Professor Hosler continued research on several fronts. She made field trips to Ecuador to carry out ethnographic and technical studies of a pottery producing community there; working with a UROP student, she completed the laboratory analysis of metal artifacts from a newly discovered ancient metal production zone in Eastern Mexico, and her article on the research results was accepted for publication in *Science*; and she continued study of the lead isotope signatures of arsenical bronze artifacts from Ecuador and Peru, with a view to determining the ore sources exploited by central and north Andean peoples in the manufacture of this bronze alloy. Professor Hosler also delivered papers at: a symposium on Aztec Economic Systems (International Congress of Americanists), a round table on the Cultural Dynamics of West and Northwest Mexico (Wenner-Gren Foundation for Anthropological Research), a lecture series of the Institute of Mesoamerican Studies (SUNY, Albany), and a symposium on The Past is a Foreign Country (Society for American Archaeology).

Dr. Michael Geselowitz (Lecturer and supervisor of the CMRAE graduate laboratory) continued his laboratory analysis of iron artifacts from both prehistoric Europe and historic North America. His publications during the academic year include: *Iron and Society in Prehistoric Slovenia: Anthropology and the History of Technology Revisited*, in Recent Trends in Archaeometallurgical Research; *For Want of a Nail: Archaeometallurgy and Dating in Historical Archaeology*, in Metals in Society: Theory Beyond Analysis; *A Review of Early Irish Ironworking*, in the Journal of Field Archaeology; and *Sutton Hoo Art: Two Millennia of History*, in Voyage to the Other World: The Legacy of Sutton Hoo. He presented a paper in a panel on North American Archaeology (Society for American Archaeology).

Dr. Ian Whitbread (Principal Research Scientist) completed his book manuscript *Greek Transport Amphorae: A Petrological and Archaeological Study*, which he submitted for publication to the British School at Athens. Dr. Whitbread ended his four years at the center as director of the CMRAE Ceramics Research Laboratory to return to Athens where he will assume the post of director of the Fitch Laboratory of the British School.

Dr. Masucci joined the center in September to begin a petrological study of Guangala Phase ceramics she had excavated at sites in southwest coastal Ecuador. She received a research grant for Latin American archaeology from the H. John Heinz III Charitable Trust to carry out a clay and mineral resource sampling survey in the region of Ecuador from which her ceramic artifacts originated. Dr. Masucci published an article on *Small Finds from Shaqadud Cave* in The Late Prehistory of the Eastern Sahel: The Mesolithic and Neolithic at Shaqadud, Sudan. She presented a paper on her Ecuadorian ceramics research at the annual meeting of the Society for American Archaeology.

Professor Heather Lechtman (Anthropology/Archaeology Program and Materials Science and Engineering) spent a month at the program in Pre-Columbian Studies at Dumbarton Oaks, Washington, D.C., carrying out a technical examination of the entire collection of Andean metal objects there. Her study is in preparation for the publication by Dumbarton Oaks of a book on Andean material culture, to which she will contribute the introductory essay, an article on Andean prehistoric metallurgy, and the technical description of the metal artifacts. Professor Lechtman published, together with the staff of the Museo Chileno de Arte Precolombino in Santiago, Chile, the book *America's*

Vanished Metalsmiths. She was named the 1992 Walter W. S. Cook Lecturer of the Institute of Fine Arts, New York University and delivered an invited lecture on that occasion as well as at a symposium on Precolumbian Archaeometry (International Symposium on Archaeometry) and another on Precolumbian Science: A Modern Perspective (American Association for the Advancement of Science).

CMRAE hosted another successful year of its Materials and Anthropology Discussion Series, which is coordinated by Dr. Geselowitz. Two of the speakers were CMRAE research staff members: Dr. Masucci, who spoke on her petrographic thin section analyses of Ecuadorian ceramics, and Dr. Whitbread whose discussion centered on the archaeological implications of image processing and micromorphology as applied to the examination and description of ancient pottery.

HEATHER LECHTMAN

Integrated Studies Program

Introduction
The Integrated Studies Program (ISP) is one of MIT's three programs designed specifically for first-year students. ISP continues to strive for an environment that is intellectually alive, moves students to make new connections among disciplines, and sharpens their ability to challenge the ideas of others and to defend their own points of view. Students spent the past year examining technologies in the context of the societies in which these technologies developed, and they augmented their coursework with hands-on application.

Having just completed the fourth year in its current format, ISP has grown from a fall term enrollment of 21 in 1988 to the point where it now attracts more students than space and staff can accommodate. A waiting list was compiled for the first time this fall. Forty freshmen entered in fall (29 men, 11 women, 6 members of underrepresented minority groups). In spring, 30 students joined ISP (20 men, 10 women, 9 members of underrepresented minority groups). To attract students of color to the ISP community, two luncheons with hands-on demonstrations were hosted during the summer Interface program.

This year, ISP welcomed Engineering Associate Professor Larry Bucciarelli to the program where he joins Arthur Steinberg, Associate Professor of Archaeology/Anthropology, as co-director. With Professor Bucciarelli's arrival, ISP has moved from a program focused on an unusual humanities course to a program with a significant engineering component. ISP has now made a major step toward its goal of integrating many of the disparate components of humanities, math, physics, chemistry, and engineering.

Academic Program
ISP offered two humanities subjects this year, "Technologies and Cultures," in fall, and "Technologies in Historical Perspective," in spring. These subjects were team taught by Professor Steinberg, Dr. Peter Dourmashkin who also teaches the ISP physics recitation, and technical instructor Chris Craig. In spring, in place of Professor Steinberg who was on sabbatical leave, Dr. Jay Wylie, an anthropologist, was an enthusiastic member of the team. Through a variety of readings, writings, and class discussions, students studied particular technologies in depth and analyzed why these technologies developed in different societies in particular ways. In addition to existing modules on clocks and time, internal combustion engines, computer technology, weaving, and blacksmithing, a new module on water systems was added this year. One highlight of the module was a student bridge design exercise, reflecting the underlying belief that students need to be introduced to elements of design early in their MIT careers. In weekly workshops students tried their hands at each of the technologies studied, and practitioners of some of these technologies supplemented regular ISP faculty and staff as workshop facilitators. Workshops were designed and taught by Mr. Craig.

In keeping with its commitment to introduce students to engineering thought and practice, ISP offered two new courses this year. In fall, all ISP students enrolled in a 6-unit seminar, "How Things Work," taught by Professor Bucciarelli, Dr. Mike Rosen, and Professor Mark Jakiela, all of the School of Engineering, with participation of Mr. Craig for the purpose of providing linkage with the humanities subject. A new 9-unit seminar on "High-Speed Ground Transportation Systems" was offered by Civil Engineering Professor Robert Whitman in spring. Professor Whitman's course culminated in a presentation by the students of their detailed proposal for a high speed rail link between Boston and New York.

In keeping with ISP's commitment to expose students to a wide range of ideas, a weekly luncheon series was held throughout the year. In these luncheons, students met a variety of MIT faculty and staff, as well as individuals of interest drawn from the surrounding community.

Reflecting the belief that students learn best by doing, students enrolled in 8.01X (fall) and 8.02X (spring), experiment-based physics subjects team-taught by Professors John King and A. P French. ISP physics recitations were taught by Dr. Dourmashkin, who also taught in the humanities course, providing a linkage between the two subjects.

Students attended science and math lectures with other first-year students, but enrolled in special recitations with their ISP classmates. Georgios Daskalapoulos, Stephen Sawin, Seth Stafford, and Charles Waldman, graduate students in the Math Department, taught the calculus recitations. Professor Kenneth Russell and graduate student Veronique Michaud of the Department of Materials Science taught the 3.091 recitation.

Marshall Hughes, Senior Staff Assistant and Debra Aczel, Program Administrator, provided support for the program during the year.

Outreach
In summer, 1991, ISP co-sponsored a summer workshop for 50 teachers primarily in vocational and bilingual classrooms. In addition to teachers from Cambridge, participants came from as far away as Chicago, Philadelphia, and Hartford. Because of the positive response to ISP's leadership in issues of public school education, similar events are planned for the future.

As part of ISP's commitment to developing partnerships with local schools, Mr. Craig spent the year in Rindge School of Technical Arts in Cambridge designing experiments for 9th grade science students as part of a project to assist Cambridge School District develop an integrated math and science curriculum.

ARTHUR STEINBERG
LARRY BUCCIARELLI

Women's Studies Program

CURRICULUM

The Program in Women's Studies offered nineteen subjects and two undergraduate seminars in academic year 1991-92, with roughly 260 students enrolled. The Program added two graduate subjects to its curriculum this year: SP411/412J Gender, Theory and Politics (joint-listed with Political Science) by Assistant Professor Elizabeth Wood (History); and SP472J Ecological Approaches to Environmental Problem Solving (joint-listed with Urban Studies and Planning) by Adjunct Professor Patricia Hynes (DUSP). In response to student requests, two undergraduate seminars were offered again this year: Sem21S60 Life Issues for Professional Women by Associate Professor Margery Resnick (Foreign Languages and Literatures); and Sem079 Gender Issues for MIT Women Students at MIT and Beyond by Lecturer Ann Russo, (Women's Studies).

Although we lost Assistant Professor Lisa Rofel's subject SP482J/483J Gender, Science and Technology when she went to the University of California, Santa Cruz, Professor Evelyn Fox Keller (Science, Technology and Society) will be offering a new subject: SP488J Gender and Science. Two other new subjects for the 1992-93 academic year are: SP423J Black Women in America: 1800 to the Present by Assistant Professor Robin Kilson (History); and SP435 Gender, Sexuality and Popular Culture by Assistant Professor Henry Jenkins (Literature).

The Women's Studies Research Room (WSSR), in the Humanities Library, funded, in part, by the Women's Studies Program, continues to be a valuable resource to Women's Studies students and faculty alike. We hope to add an on-line computer to the WSRR in the coming academic year, to enhance its usefulness as a research room.

STUDENTS

Since the Women's Studies minor was instituted three years ago, nine students have graduated with that designation, and four other students are completing the coursework for the minor. Ten 1992 graduates are concentrating in Women's Studies, with twelve current underclassers already declared. Three undergraduates are actively considering majoring in Women's Studies.

The Graduate Student/Faculty Luncheon Seminar Series continued this year, with presentations on moral constructions of poverty, technology for women in Africa, images of infertility in the media, and women in the labor movement in Japan, presented in conjunction with the MIT Japan Program. The series provided graduate students pursuing research on women and/or gender issues in various departments throughout the Institute with an opportunity to present work-in-progress to those with similar interests in other disciplines.

PROGRAMS AND SPECIAL EVENTS

The annual speaker series on *Black Women Writers*, supplementing SP433J Black Women Writers, brought to campus three exceptional writers: Toni Morrison, in conjunction with the Abramowitz Lecture; Toni Cade Bambara, in conjunction with the Artist-in-Residence program; and Jewelle Gomez, in conjunction with Lesbian and Gay Studies. Women's Studies worked in close collaboration with the Office of the Arts on the Toni Morrison and Toni Cade Bambara visits, both of which were highly visible events attended by many members of the MIT community. Our series on *Women and Politics*, co-sponsored by the Department of Political Science and the Center for International Studies, brought four speakers.

Women's Studies also worked with Cultural Studies this year to create four very successful events: a lunch discussion on Chicana poetry with Mary Louise Pratt (Stanford); a lecture on 'political correctness' by Joan Wallach Scott (Princeton); an afternoon lecture on popular culture by Lillian Robinson; and a day-long symposium "Engendering China: Women, Culture and the State." Women's Studies co-sponsored a lecture with the Technology and Culture Seminar by Elaine Bernard of Harvard University, author of "Women Changing Technology Changing Women."

During IAP, the Program arranged to repeat last year's discussion "What is Feminism?" with panelists Robyn Ochs, Ayida Mthembu, and Visiting Assistant Professor Sherifa Zuhur (History), and co-sponsored a reading by poet Joy

Harjo with the Poetry at the Media Lab series. Our most ambitious IAP project was a five-part seminar series, "Race, Gender and Ethnicity in US Politics," sponsored with the Political Science Department. At the request of graduate students and post-doctoral women, Women's Studies also organized a lunch series on "Women's Lives in Science and Engineering." In addition to these IAP offerings, the Program sponsored both a Freshman Exploration and an Interphase luncheon to offer new MIT students an opportunity to meet Women's Studies faculty informally and to learn about the interdisciplinary nature of Women's Studies.

Three major events this year reinforced the reputation of the MIT Women's Studies Program as serving the greater Boston/Cambridge Women's Studies community. In the fall, the Program hosted a fifteenth anniversary poetry reading and party for Transition House, a shelter for battered women. In the spring, Women's Studies worked with *Sojourner*, the women's newspaper which originated at MIT, to sponsor an evening of feminist comediennes in Kresge auditorium. This event sold out, and we are discussing the possibility of repeating it next year. Finally, with Wellesley College and Emerson College, as well as a number of other departments and offices at MIT, Women's Studies offered a film series, "Black Women Filmmakers: Vision and Image," highlighting the works of three independent women filmmakers.

The Program in Women's Studies became the home this year for the MIT Women's Oral History Project. Coordinated by Professor Charles Weiner (Science, Technology and Society Program) and Professor Resnick (Foreign Languages and Literatures Section), this project utilizes undergraduate women to interview MIT alumnae for an archive to be housed at MIT. The six undergraduates who worked on the project during the 1991-92 year were excited and inspired by the women they interviewed. Housing the project in Women's Studies provides these undergraduate interviewers more contact with each other, as well as an academic framework within which to evaluate their experiences as both observers of and participants in MIT's unique culture.

For the first time in a number of years, the Program hosted a major conference this spring, "En/Gendering Environmental Thinking: A Symposium of Scholars, Strategists and Community Activists," which attracted 150 participants from around the country. This three-day symposium was designed to encourage dialogue about environmental issues among students and faculty in science and engineering at MIT, policymakers, and environmental activists from other parts of the country. Twenty-seven speakers participated in six panels dealing with environmental issues in women's lives in rural and urban settings, in both the "First" and the "Third" World, in the context of military, industrial, and governmental institutions, and how women internationally have worked against environmental degradation. The entire conference was taped and high-quality cassettes will be available for purchase. Two wrap-up workshops ended the conference: 1) to design engineering curricula to include more materials pertaining to global environmental issues 2) to generate scientific research agendas responding to the articulated needs of citizens' groups. The conference was an enormous success. Several notices about it have appeared in local papers, and stories have been commissioned for national journals.

RESEARCH AND PUBLICATIONS

Our publication, *Women's Studies Around Boston*, was sent to a mailing list of 2,500 this year. We produced four editions of the newsletter and the response to this increased frequency was striking. We have gotten many more requests for subscriptions. This publication provides vital links between the Program at MIT and Women's Studies scholars at other institutions and in the community.

The Women's Studies Faculty continued their active contributions to their individual fields, and most of these accomplishments are listed in the reports of their home departments. What follows are the contributions made by Women's Studies faculty members particularly to intellectual explorations of sex and gender. The activity of this faculty is strikingly international. Professor Jean Jackson (Anthropology/Archaeology) published "Rituales Tukano de Violencia Sexual" in a Columbian journal of anthropology as well as "The Meaning and Message of Symbolic Sexual Violence in Tukanoan Ritual" in the *Anthropological Quarterly*. Associate Professor Isabelle de Courtivron's (Foreign Languages and Literatures) biography, *Clara Malraux: Une femme dans le siecle* was published in April in France, by Le Seuil, and received rave reviews in *Figaro litteraire*. Professor Louis Kampf (Literature) spoke on curriculum and gender at the International Congress of Comparative Literature in Tokyo. Professor Hynes' book *The Recurring Silent Spring* was translated and published in German and Japanese. Hynes also produced another book on gender and environmental policy this year, *Reconstructing Babylon* (Indiana University Press), and three articles: "Feminism and Engineering: the Inroads," "Pollution and Pornography," and

"Rachael Carson: The Vision Splendid Before Her Eyes." She delivered lectures on aspects of engineering and public policy, and women and the global environment, in Oslo, Norway, Detroit, Pittsburgh, Stanford University, University of Michigan, University of Illinois, University of California at Santa Barbara, and University of Missouri among others. Professor Susan Carey (Brain and Cognitive Sciences) spoke to the Royal Society of London on "Becoming a Face Expert" and published a book with Rochelle Gelman on *The Epigenesis of Mind.* Professor Jenkins, winner this year of the Edgerton Award, presented papers on representations of gender in the media in Norwich, England and London as well as Pittsburgh, Iowa City, Indianapolis, and Cambridge. He is a member of the steering committee for the Critical Studies in Paris program. His book, *Textual Poachers: Television Fans and Participatory Culture*, is due out from Routledge next year. Professor Resnick was one of the organizers of a major feminist conference in Madrid, Spain: "Septimo Coloquio sobre la Mujer Espanola en el primer centario." She supervised the completion of six oral histories of MIT alumnae for the Oral History Project, including three from the class of '22. She served on the Women and Public Policy Initiative Group, a group of public officials, CEOs, and academics, and on the "Pathways for Women in Science" project at the Wellesley Center for Research on Women. Professor David Halperin (Literature), who will be a Visiting Fellow at the Humanities Research Centre in Canberra, Australia, next spring, founded a new journal this year (*GLO: A Quarterly Journal of Lesbian and Gay Studies*), chaired the seminar in Gay and Lesbian Studies at the Center for Literary and Cultural Studies at Harvard, published two articles on Plato ("*Plato and the Metaphysics of Desire*" and "*Plato and the Erotics of Narrativity*") and two book reviews, co-chaired the Lesbian/Gay Caucus of the American Philological Association as well as serving on the Committee on the Status of Women and Minority Groups for that organization, and gave 21 invited lectures on the social construction of sexuality, including at the University of Chicago, Cornell, Princeton, Harvard, Vanderbilt, Brooklyn College, Boston College Law School, Harvard Law School, and the University of California at Berkeley. Professor Wood finished two articles, one circulating and one to be published in *Sexuality and the Body in Russian Culture* (Stanford University Press), a book review in *The Women's Review of Books*, two invited lectures and a conference paper. She won three grants for her work on post-revolutionary Russia for 1992: the Kennan Institute for Advanced Russian Studies Research Fellowship, the International Research and Exchanges Board Fellowship, and an NEH summer stipend. Professor Ruth Perry published three articles this year: "Mary Gordon's Mothers" in *Narrating Mothers* (University of Tennessee Press); "Colonizing the Breast: Sexuality and Maternity in Eighteenth-Century England" in *Journal of the History of Sexuality and reprinted in Eighteenth-Century Life* and *Forbidden History* (University of Chicago Press); and "A Short History of the Term 'Politically Correct'" in *Beyond PC* (Graywolf Press). She also published a Preface to *In the Shadow of Olympus: German Women Writers of the Eighteenth Century* (SUNY Press) as well as four book reviews. She gave a paper on "En/Gendering Environmental Thinking" at a conference on Feminism, Science and Philosophy in Valencia, Spain, and three other invited lectures. She is co-chair of the Board of Representatives for the Graduate Consortium in Women's Studies at Radcliffe. Professor Sherry Turkle's (Science, Technology and Society) *Psychoanalytic Politics: Freud's French Revolution* has been revised and updated for a second edition, and she published five new papers this year: "Epistemological Pluralism and the Revaluation of the Concrete" in the *Journal of Mathematical Behavior* ; "Computational Seductions: The Roots of Computer Holding Power" in *Demystifying Media Technology*; "Psychoanalytic Culture: Jacques Lacan and the Social Appropriation of Psychoanalysis" in *Telling Facts: History and Narration in Psychoanalysis*; "Paradoxical Reactions and Powerful Ideas: Educational Computing in a Department of Physics" in *Sociomedia, Hypermedia, and the Social Construction of Knowledge*; and "Romantic Reactions: Paradoxical Responses to the Computer Presence" in *The Boundaries of Humanity: Humans, Animals, and Machines.* She gave several keynote addresses and invited lectures in Tokyo, Barcelona, New York, Cornell and MIT. Senior Lecturer Caroline Whitbeck published "Ethical Issues Raised by New Medical Technologies" in *Women and New Reproductive Technologies: Medical, Psychosocial, Legal and Ethical Dilemmas;* and Lecturer Ann Russo published two articles in *Sojourner.*

RUTH PERRY

SLOAN SCHOOL OF MANAGEMENT

Feeling the need to fundamentally change what and how we teach our masters students, the 1992-92 school year was dominated by a school-wide effort to develop the broad operating principles of a new curriculum. Having done this, the 1992-93 school year will be devoted to developing the specific courses necessary to implement that new curriculum. Implementation could then begin in the 1993-94 school year.

The essential idea is to start with three views of management -- the market view, the management science view, and the behavior view -- and to then follow this up with a series of course offerings where students would be required to take "y" courses from a list of "x" courses. Choice would be expanded, but everyone would be required to understand differing viewpoints.

TEACHING PROGRAMS

Undergraduate Program

During the 1990-91 school year, 48 seniors majoring in management science were graduated. Of those 48 seniors, eighteen chose an option in information technologies, nine selected marketing research, two concentrated in behavioral science, and eight in operations research. Of the remaining eleven students who were pursuing other specially approved subjects, nine chose an option in finance, and two in international management.

Ten of our graduates also received bachelor's degrees from other departments: four from the Department of Electrical Engineering and Computer Science, two from the Department of Mechanical Engineering and two from the Departments of Economics, Mathematics, and one each from the Departments of Civil Engineering, Chemical Engineering, Biology, and Economics. One student received simultaneously the SB degree in Management Science and the SM degree Electrical Engineering.

At a post commencement reception, the Department recognized Sarah I. King, a June graduate majoring in management science, by presenting her the Sloan School of Management Senior Prize. Awarded to outstanding senior management students, this prize, given annually, honors students who have achieved high scholastic standing and have demonstrated leadership and professional promise.

This spring 119 students were enrolled in the Management Science Program, including 18 who were enrolled in management science as their second SB department. (Enrollment figures are based on the registrar's fifth week counts.)

Seventy of our continuing undergraduates have declared their options as follows:

Regular Options	
Information Technologies	28
Marketing Research	14
Behavioral Science	9
Operations Research	3
Special Options	
Finance	13
International Management	1
System Dynamics	1

A large number of students from other MIT degree programs continue to enroll in our undergraduate subjects. There were 333 such enrollments during the 1991-92 academic year, representing the classroom equivalent of 37 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 62 additional undergraduates in our program, for an equivalent total of 181.

Faculty serving as undergraduate advisors were Professors Thomas J. Allen, Dimitris J. Bertsimas, Ravi Bhushan, Wujin Chu, Steven D. Eppinger, Stephen C. Graves, Rebecca M. Henderson, John C. Little, James B. Orlin, and Michael A. Rappa, along with Dr. Jeffrey A. Meldman, Director of Undergraduate Programs, Dr. Peter J. Kempthorne, Mr. David R. Breakstone, and Ms. Hillary De Baun, Program Administrator. Professor Anantaram Balakrishnan continued as coordinator of MIT's Undergraduate Research Opportunities Program (UROP) and Mr. Breakstone served as coordinator in management science for phase two of the Institute writing requirement. Dr. Meldman served as chair of the Undergraduate Advisors Committee and as IAP coordinator, and Ms. De Baun served as IAP administrative coordinator.

Faculty serving on the Undergraduate Policy Committee included Professors Allen, Orlin, and Abraham J. Siegel. Dean Jeffrey A. Barks, Dr. Meldman, and Ms. De Baun served ex offiis, and Professor John D. C. Little chaired the committee.

During January 1991 we offered our IAP activity "Organizational Reality" for the third year. This intensive series of classes, readings, and exercises to introduce MIT undergraduates to the important realities of working in organizations drew mostly students majoring in engineering and science. This series, designed primarily for students in science and engineering disciplines, was led by Professor Abraham J. Siegel and Dr. Jeffrey A. Meldman and involved the coordinated participation of 15 management faculty, a panel of mid-career students in our Management of Technology program, and two MIT alumni from the corporate sector.

In October, Dr. Meldman coordinated a panel and discussion at the Sloan School following the final event of President Vest's inaugural year: An MIT Colloquim, Teaching Within a Research University. The evening started with a panel made up of Professors Graves, Henderson, Little, Robert B. McKersie, and Dean Thurow who established the focal points for later discussion in smaller, breakout groups of Sloan students, faculty, and staff. Discussion groups were led by Professors Allen, Rappa and Marcie J. Tyre.

During January, 1992 we offered several IAP activities: The Foreign Currency Exchange Bourse Games, offered for the fifth year in conjunction with Citibank, was coordinated by Professor Jiang Wang: Dr. Jeffrey Meldman and Professor Judith A. Lachman conducted sessions in Dr. Meldman's series "A Brief Introduction to Law;" "The System Dynamics Approach to Organizational Learning" was sponsored by Professor John Sterman and Professors Steven Eppinger and Karl Ulrich held a day-long design thesis workshop.

In addition to participating in IAP, members of our faculty contributed to the undergraduate educational commons throughout the year in the following ways: Professor John Little was a freshman advisor, while Professors Graves and Rappa, Dean Thurow, and Dr. Meldman also advised freshmen and conducted freshman advisor seminars for their advisees. Twelve of our faculty served on Institute committees related to undergraduate educational policy or to our undergraduate program; Professor Stephan Schrader served on the Faculty Policy Committee; Professor John S. Carroll chaired the Committee on Student Affairs, and also served as a member of the Committee on Operations Research, along with Professors John Little, Glen L. Urban, and Gabriel R. Bitran. Professor T. L. Magnanti served as cochair for the Committee on Operations Research; Professor Steven Eppinger served on the Committee on the Writing Requirement and Professors T. J. Allen chaired and Lisa M. Lynch served on the Athletic Board. Professors J. D. Nyhart and Judith Lachman served on the Prelaw Advisory Council, along with Dr. Meldman who also served on the committee on the Use of Humans as Experimental Subjects. Forty-six faculty supervised UROP projects for students from departments throughout the Institute.

Master's Program

The 1991/92 academic year was one of response, on all fronts, to the self-study of the previous year. A Core Reassessment Committee, composed of faculty, students, and administrators, evaluated our set of required courses and developed a proposal for a new core, to be finalized this fall. If approved, curriculum development will occur over the next year, with implementation beginning in fall 1993.

A faculty Committee on Teaching Quality set up initiatives to evaluate teaching performance. Efforts are also underway to develop seminars and workshops focused on helping faculty upgrade their classroom skills.

Physical facilities, particularly those most used by students, were improved, with the Schell Room redesigned and dedicated to group study space, classrooms rejuvenated, and telephones and fax machines installed for student job search use.

Students ran the 1991 orientation exercises, to School-wide acclaim. The week of activities set an excellent tone for the new year, bringing first and second year students together with great community spirit. Other initiatives to integrate the community included the Lunch with a Professor series, Town Meetings, and Lunch with Lester. A Student Senate was formed, as a mechanism for channeling student involvement in Sloan activities and policy-making.

Students designed new methods to share their international cultural diversity. Country Seminars focused the spotlight each week on a different nation or world region, as students presented lectures on their home countries over a meal of native cuisine. The Japan/Korea Trip and the Eastern European Trip again offered opportunities for business and cultural study.

Admissions efforts to recruit the best applicants to the School were intensified by the inauguration of an alumni/ae interviewing project and a strengthening of our existing Sloan Ambassadors program. Competition for admissions was higher than ever, and the entering class, including Leaders for Manufacturing students, totaled 244. The following table presents a profile of the graduate classes of 1992 and 1993:

Profile of Graduating Master's Classes	*1992*	*1993**
Number of Candidates:	250	244
US Citizens	154	156
Foreign Citizens	96	88
Women	63	49
Members of Minority Groups	31	27
Median GMAT score	650	650
Undergraduate Grade-Point average (out of 5.0)	4.3	4.4
Undergraduate Majors:		
Social Sciences and Humanities	27%	36%
Physical Sciences	14%	8%
Engineering	47%	47%
Pre-Professional	12%	9%
Average Years Full-Time Work Experience	4.4	4.2
Mean Age at Admission	27	27

*Projected

Career Development Office

In 1992, the economy continued to challenge master's students in their search for both permanent and summer employment. Most firms took a conservative approach to recruiting, projecting hiring needs consistent with or below 1991 figures. The cautious mood was established early in the fall (with an 8% drop in companies making presentations to students about the career opportunities they offered) and remained in place through the winter. Level or reduced recruiting occurred within the following industries: computers, software, pharmaceuticals, investment banking (corporate finance roles), commercial banking, venture capital, and real estate.

Luckily, spring brought a gentle thaw both in economic conditions and in companies' hiring behaviors. By season's end, the number of firms interviewing first and second-year students, the number of interview

schedules filled, and the total number of interviews held all rose slightly compared with 1991. Companies most actively pursuing Sloan candidates included consulting firms, the sales and trading functions within investment banks, manufacturing organizations, smaller businesses, and key Sloan sponsors already demonstrating interest in our product through program/research support.

The ultimate placement picture for the Class of 1992 presents an even brighter picture! Placement questionnaires completed by graduating students indicate that candidates received an average of three job offers, consistent with the past several years. Starting base salaries ranged from $34,500 to $100,000 with a mean of $62,900 (up from $61,000 last year). The median salary was $60,000 which parallels 1991.

The distribution of Class of 1992 members across job functions, industries, and locations closely resembled 1991 patterns. Consulting, electronics, and investment banking proved to be the most popular industries, respectively attracting 29%, 15% and 13% of the students reporting placement. The three top job functions entered were consulting (27%), finance (24%), and manufacturing/operations (17%). The highest percentage of students (24%) will work in Massachusetts, with New York City (17%), and international (17%) locations next in popularity.

So, in the final analysis, Sloan School graduates secured excellent jobs at highly competitive wages again this year, despite prevailing economic conditions. Students fared extremely well in the marketplace, contradicting the belief some hold that the glow is off the MBA. Such appears to not be the case, at least for graduates of the nation's leading programs. Quality still sells even (perhaps especially!) in tough times.

Alumni/ae Relations

Alumni/ae Relations continues to offer new programs which are designed to meet the needs of the School's graduates. In October, 1991, the Sloan Master's Convocation was held in Cambridge and focused on "Technology: Revolutionizing the Way the World Does Business." Later in October, a mini-convocation on "New Industrial Strategies for the New Europe: Who Will Align With Whom?" was held in Paris and featured faculty and European business leaders.

Our regional alumni/ae clubs sponsored a variety of events for alumni/ae which featured faculty and local business leaders. Club events were held in Boston, New York, Washington, DC., Northern California, Southern California, and Spain. Plans are underway for increased activities for all lubs and for club development in the United Kingdom and other U.S. regional areas.

During June 4-7, 1992, Sloan welcomed members from the Classes of 1967, 1972, 1977, 1982, and 1987, for a weekend of events which included "Tech Night" at Boston Pops, Technology Day which featured talks and discussions on "Winds of Change: Global Business Excellence in the 21st Century," a Friday Evening Consumption Function, a Spirit of Boston Harbor Cruise, a Day at the New England Aquarium, a Pre-game Party and Red Sox game at Fenway, and a Reception and Dinner Dance at the Cambridge Marriott. Thanks to the volunteer efforts of alumni/are volunteers, we had a record attendance for our 1992 reunion which includes a record return from the 25th-year class (34%)!

Alumni/ae continue to actively support the efforts of the School through various volunteer programs. Boston alumni/ae participated in the new Alumni/ae-Student Dinner Program where alumni/ae opened their homes to students to share and discuss opportunities in their industry, the current job market of the industry, and lifestyle issues. The Mentor Program will be expanded to include more student and alumni/ae participation and alumni/ae from Boston, New York, Northern California and Southern California will be asked to participate in the Mentor Program. Alumni/ae also supported the new Alumni/ae Interviewing Program for admissions and participated in the admissions recruitment evenings and Career Development Office activities.

In order to facilitate the Sloan networking opportunities, a new Sloan alumni/ae directory will be published and be provided to all graduates in January, 1993.

The directory will feature an alphabetical listing of all Sloan graduates with home and business information, as well as corporation, geographical, and program/class indices.

Sloan's Alumni/ae Relations continues to connect alumni/ae to the global network of Sloan alumni/ae and to facilitate active alumni/ae involvement in educational and social activities, both regionally and at Sloan.

Alfred P. Sloan Fellows Program
On June 1, 1992, 54 Alfred P. Sloan Fellows were awarded the degree of Master of Science in Management. The Class of 1992 represented a broad diversity of backgrounds and interests, and again was drawn from organizations from the United States and abroad. The Sloan Fellows Program was the first executive education program in the United States and is now in its 60th year. Just prior to their graduation, the Sloan Fellows completed a three-week International Management Field Trip to Russia, Czechoslovakia , and Germany where they met with top government and industrial leaders.

The demand for the program continues to be strong and the quality of the nominations extremely high. On June 12, 1992, with a total of 56 participants .

The Director of the Sloan Fellows Program, Dr. Charles Grader is an alumnus of the program (Class of 1974). Professor Robert McKersie is the Chair of the Faculty Program Committee, and Ms. Eleanor Chin is Program Coordinator.

The Sloan Fellows Program is the oldest executive education program in the United States, and is now in its 61st year.

Program for Senior Executives
Professor Michael Scott Morton continues as Chair of the Program Faculty. Dr. Peter Gil will assume new duties as Director, External Relations, and Ms Susan Lowance has been appointed Director of the Senior Executive Program, effective August 1, 1992. Susan has directed the Smith College Management Program.

The Program notes several firsts: participants from Eastern Europe; the first Native American participant, who is preparing to head the US Bureau of Indian Affairs (also a first).

Major changes and additions are being prepared; e.g., a reduction of the program length from nine weeks to eight, a re-introduction of an international field trip and greater interaction between participants and faculty.

International Collaboration: MIT/NTU
The Sloan School has signed a five-year contract with the Nanyang Technological University (NTU) to assist in the development of a comprehensive business school in Singapore. Under the agreement, MIT faculty visit NTU to offer research seminars, participate in the development of curricula, and meet with students and faculty. Additionally, NTU faculty participate in Sloan School programs as visiting scholars.

A further objective of the collaboration is cooperative research projects. At the end of the second year of the collaboration, all of these activities were well underway.

MIP-MIT Executive Education Program
International initiatives for Sloan were a focus of activity this year as the Sloan School and MIP-Politecnico (a consortium comprising the Polytechnico di Milano and approximately 25 public and private Italian companies) launched an intensive general management program for mid-career executives. The MIP-MIT Executive Program will meet for a total of three weeks in Milan and three weeks at MIT and is intended to provide a unique opportunity for an international comparison of critical issues in management.

STOA Program
Sloan continues its institution building relationship with STOA, a non-profit corporation formed by IRI for the purpose of providing post-graduate management education in Italy.

Sloan provides curricular advice and educational resources. Over the last year, Professors Lessard, Locke, Lynch, Rosenfield, Ulrich, and Westney have each taught at STOA for one to two weeks. The program will continue for one more year, as Sloan works to solidify accomplishments made and help STOA put in place a structure to move into the future.

Management of Technology Program
The MIT Management of Technology Program (MOT) was established in 1981 and is the only program of its kind. Administered jointly by the Sloan School of Management and the School of Engineering, this 12-month, full-time program leads to the degree Master of Science in the Management of Technology. It is aimed at engineering and science managers with eight to twelve years of work experience, and strives to prepare them for senior roles in industry and government where they will assume leadership positions in the creation and growth of technology-based endeavors.

In spite of the continuing weakened economy internationally, a record 45 participants are enrolled in class of 1992-1993, up from 40 in 1991-1992. As is the goal, approximately half of the class is international. Marketing efforts continue to build the program towards a desired full complement of 50-55 participants.

The curriculum is now stable and well-accepted by the students and their sponsoring organizations. The expanded field trip has gone well. In 1991 and 1992 the class went to California. Future trips will be planned to include countries outside of the United States.

The joint activities and subjects for the Sloan Fellows and MOT participants have been an overwhelming success. These have been expanded during 1992-1993 and included a session with the participants in the MIP-MIT Executive Education Program (a joint program with the Polytechnico di Milano).

Rochelle Weichman is the Director of the MOT Program; Professors Edward B. Roberts of the Sloan School and Thomas H. Lee of the Department of Electrical Engineering and Computer Science continued as Co-Chairmen of the Program.

The Ph.D. Program
During 1991-92, 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 464 applications, we made 35 admission offers and had 25 (70%) acceptances, distributed among 3 areas:

Finance and Accounting	5 (1 US female, 3 Foreign males,1 US Male)
Management Science	9 (5 US males-4 foreign males)
Behavioral Policy Sciences	12 (3 US females, 2 foreign males, 3 Foreign females,3 US males, 1 under-represented minority)

The overall percentage of US applicants was 35% and the foreign applications 65% while the largest number of applications were 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 and underrepresented minority applicants, and work on our own strategies for identifying prospects and sources. The bulk of the program's graduates pursue academic careers.

The Doctoral Program Committee, headed by Professor James B. Orlin and coordinated by Sharon Cayley, continues to grapple with the diverse problems of a very individualized program, including addressing time taken to complete the program (four and a half years) through early research ties to faculty, and financial aid awards that are competitive with our principal rivals.

Summer Programs
School of Management faculty participated in three MIT Special Summer Program courses. The two one-week programs were New Technologies for Decision Support and System Dynamics: Microcomputer

Simulation of Corporate Strategy and Social Systems. The third course, Management of Research, Development and Technology-Based Innovation, was two-weeks long.

In addition to the MIT Special Summer Program courses, the Sloan School offered five one-week Special Executive Programs. Two have been available for several years (Corporate Strategy and Financial Management) and the other three (Complex Organizations, Japanese Technologies and Management Issues for Corporate Counsel) were introduced in 1990. All continued to draw senior executives from international private and public sectors.

RESEARCH

Economics, Finance, and Accounting
Faculty research in Economics, Finance, and Accounting applies the tools of economic theory, statistics, and operations research to a wide range of problems. Work is directed to issues of economic policy, to problems in pure theory, to empirical questions, and to the development of improved decision-making methods for practicing managers.

Applied Economics. Professor Ernst R. Berndt published results from a number of research projects, including the impacts of managerial background and corporate governance structure on company performance in the U.S. rail industry, the cost effects of mergers, the effects on private sector productivity growth of public infrastructure investments, and the measurement of price change (adjusted for quality improvements) in the U.S. pharmaceutical industry.

Professor S. Lael Brainard is engaged in research on strategic trade policy and on structural unemployment, using analytical and empirical techniques from economics. She taught classes on international trade and competition and on international macroeconomics.

Professor Henry D. Jacoby's research is on the analysis of energy and resource projects, using methods of modern corporate finance, and on economics and policy issues of global environmental change.

Professor Robert S. Pindyck continued his research on irreversible investment decisions, focusing on investments of uncertain cost, and capital replacement decisions. He also continued his research on commodity markets and financial markets, testing the present value model of rational commodity pricing.

Professor Nancy L. Rose continued her work on the determinants and effects of government regulatory policies. Her current research projects include an investigation of airline service quality provision and an analysis of executive compensation practices in regulated industries. In the fall of 1990 she was appointed the Director of the National Bureau of Economic Research Program in Industrial Organization. She has been named an Alfred P. Sloan Foundation Fellow for 1991-1993.

Professor Julio J. Rotemberg has continued his work on the ways in which imperfect competition among firms exacerbates the business cycle. He has shown that, empirically, imperfect competition is helpful in understanding the effects of energy price increases on economic activity. In collaboration with James Poterba of the Economics Department and John Driscoll, a graduate student at Harvard, he has proposed a new method for measuring the stock of money and shown that it is highly correlated with economic activity.

Professor Richard L. Schmalensee was named Director of the Center of Energy and Environmental Policy research. His research focuses on the economics of environmental policy.

Professor Thomas M. Stoker has continued his work on the development of semi-parametric estimation techniques and their application to economic problems. He has also done further work on the implications of aggregation for the analysis of consumer demand.

Professor Alwyn Young continued his research on the implications of bounded learning by doing for comparative advantage and long-run growth. He also developed measures of the contribution of structural adjustment to GNP growth.

Finance. Professor John C. Cox continued his work on intertemporal consumption and portfolio policies. In work with Chi-fu Huang, he analyzed the existence and characteristics of optimal policies, and also studied their equilibrium properties. He has also begun work on the intertemporal dependencies of security returns.

Professor John Heaton is investigating equilibrium models of savings and portfolio choice where individuals cannot diversify away their individual income risk. The goal is to better understand aggregate savings and the dynamics of asset returns. Over the past year he taught Finance Theory and Monetary Economics III.

Professor Chi-fu Huang has worked on optimal consumption-portfolio policies for preferences that exhibit local substitution. He has also worked on an inverse optimal portfolio problem and an empirical investigation of the auctions of Treasury bills.

Professor Andrew Lo has developed a new Ph.D. course on empirical techniques in financial economics, with particular emphasis on applications to stock and bond market data. His research has focused on the sources and nature of predictability in recent stock and bond market returns, and how economic conditions affect such predictability over various investment horizons. Professor Lo also organized and taught a faculty minicourse entitled "Finance Made Difficult," in which over 130 MIT faculty participated from June 8-12. In July 1991, Professor Lo was named one of the primary editors of the Review of Financial Studies. He was awarded a Sloan Foundation Research Fellowship in 1992, and also received the Sloan Teacher-of-the-Year Award.

Institute Professor Franco Modigliani has completed a survey of the literature on the Life Cycle Hypothesis, which will appear in Pal grave Encyclopedia. He has also continued his research on saving behavior by undertaking an analysis of saving in China--which has had a most extraordinary and baffling behavior in recent years. Another investigation deals with the relation between growth and saving on the one hand, and growth and investment on the other. He has completed work begun last year together with Frank Fabozzi, on a textbook, Capital Markets, Institutions, and Instruments, which has since appeared in print (Prentice-Hall). Another joint undertaking with Frank Fabozzi is a book on the mortgage market, Mortgage and Mortgage-backed Securities Markets (Harvard Business School Press).

Professor Stewart C. Myers' main current research project tests alternative theories of corporate financing behavior. He and Professor Lakshmi Shyam-Sunder are investigating the power of traditional statistical methods and developing new tests for a large sample of U.S. companies. Professor Myers is also extending previous applied work on alternative methods for estimating the cost of capital.

Professor David Scharfstein has been doing research on a wide variety of topics in corporate finance. His recent projects include analyses of Japanese corporate financing arrangements, the economics of financial distress, and corporate debt structure.

Professor Jeremy C. Stein continues to work on a broad range of theoretical and empirical topics in corporate finance and asset pricing. His current research includes an analysis of the macroeconomic consequences of "bank-dependent" firms, and an examination of corporate risk management strategies.

Professor Jean-Luc Vila is currently studying the impact of various market imperfections, such as transaction costs or leverage constraints, on the behavior of economic agents in financial markets. He is also continuing his research in the area of economics of information.

Professor Jiang Wang has been working on equilibrium models of dynamic stock prices and trading volume under asymmetric information. He is also working on the problem of optimal contracting between investors and money managers.

Accounting. Professor Andrew W. Alford continued to work with Mark E. Zmijewski at the University of Chicago on stock price effects of delayed interim earnings releases.

He also began work with Mark and Jennifer J. Jones, also at the University of Chicago, on firms' filing behavior of annual financial statement data on Form 10-K with the Securities and Exchange Commission.

Professor Paul Asquith finished his second paper on convertible bonds and a paper on financial distress. He began work on a second paper on financial distress and on equity short sales.

Professor Ravi Bhushan work has been in the area of efficiency of capital markets. In one paper that he wrote this year, he shows that the magnitude of the delayed price reaction to earnings announcements is inversely related to a company's analyst following. In another project, he is examining how global fund managers' investment styles and skills affect their approaches toward coping with international accounting diversity and their investment decisions.

Professor Paul M. Healy has worked on three research areas. The first examines how firms perform after mergers and acquisitions. The second examines problems faced by firms' managers in communicating information on their firms' performance to outside investors. The final research topic examines how trends toward globalization of financial and product markets have affected cross-country merger and acquisition activity.

Professor Alfredo Kofman is working on the design of new performance measurement, evaluation, and incentive systems. He is testing the implications of his conceptual models in the manufacturing companies associated with the Leaders for Manufacturing program. He is also studying the impact of management information systems on organizational learning and modeling the incentive mechanisms that may lead managers to behave in counterproductive or myopic ways. Professor Kofman has continued his research on collusion-proof mechanism design and optimal communication algorithms.

Professor Uri Ronnen has continued his work on quality standards Contrary to the prevailing literature on the subject, he has argued that when production involves quality-dependent fixed costs, an appropriately chosen standard will enhance price competition and increase consumers' participation and welfare.

Management Science

The Management Science area encompasses the following concentrations: marketing, operations management, information technology, probability and statistics, and operations research. New initiatives, are being implemented by the members of the area. Several faculty in Management Science participate and coordinate a workshop on the management of quality as applied to the Sloan School. Steven Eppinger and Karl Ulrich are playing a major role in the introduction of a new module on the management of technology with an emphasis on manufacturing. Thomas Magnanti established the Decision Sciences Program which will coordinate and stimulate activities across the Institute. In addition to these initiatives, several important research topics are being undertaken. These include: the modeling of variability in manufacturing systems, the management of quality, capacity expansion models for telecommunication networks, models to aid the management of software development and measures of software productivity, economic impact of information technology, and the integration of marketing and engineering.

Members of all the subgroups have continued to play a role in the Leaders for Manufacturing Program (LFM) in a wide variety of functions. In particular Tom Magnanti is a co-director of the program. A significant number of LFM students have been and are being advised by faculty of the Management Science area.

Awards and Honors: Professor Ulrich received the ASME Design for Manufacturing Committee 1991 Best Paper Award for his paper *Fundamentals of Product Modularity.*
Professor Magnanti received M.I.T.'s Gordon Y. Billard Award for exemplary service and was named the class of 1960 faculty fellow.

Operations Management
Professor Gabriel R. Bitran has been working on the development of models to analyze manufacturing operations with variable yields.

These are typical of semiconductor manufacturing and other high technology environments, such as fiber optics. He has continued his research in the service industry studying reservation systems. The context in which the study is being performed is the hotel industry. The objective is to develop models to allow managers to match supply and demand. Professor Bitran continues to work on a methodology for assessing the status of quality in services. He has also started a research project on the catalog industry.

Professor Stephen C. Graves's work continues to focus on understanding the value of production flexibility in various forms, and on modeling variability in manufacturing systems. He is supervising LFM projects at Kodak, General Motors, and Boeing.

Professor Charles H. Fine continues his research on quality management. In addition, he has been focusing recently on research and LFM course development on management control emphasizing how accounting and information systems can affect manufacturing competitiveness.

Professor Lawrence Wein continues to develop new methods and principles for the scheduling and control of production operations, as modeled by a network of queues. He has also worked on some quality control issues in semiconductor manufacturing and printed circuit board assembly.

Professor Karl T. Ulrich is pursuing several projects on tools, theories, and methodologies for product development. His current research partners include The Boeing Company and The Stanley Works.

Professor Steven Eppinger's research activities include projects aimed at improving product design procedures and manufacturing process control techniques. He also conducts research projects within M.I.T. Laboratory for Manufacturing and Productivity, with funding from NSF, Digital, ICRMOT, IMVP, and LFM.

Professor Anantaram Balakrishnan continues to work on effective optimization models for process planning in metal forming operations, sequencing and scheduling printed circuit board assembly operations, electronics circuit diagnosis, and telecommunication system design.

Operations Research and Statistics
Using statistical and probability methods. Professor Arnold Barnett has studied subjects that shape public policy, particularly in the areas of aviation safety and criminal justice. He has also done recent work on voting systems, war casualties, and the question "when is a model good enough?"

Professor Gordon Kaufman continues to focus on the exploration and exploitation of primary energy resources and on statistical and mathematical problems in resource estimation. He has also been applying his methodology to the problem of characterizing large system software failures.

In addition, Professor Roy Welsch has studied nonlinear regression for exponential family models, the use of graphics in statistical analysis, computer guided diagnostics in statistics, and new methods for variable selection in regression, and risk management in financial credit services.

Professor Bin Zhou focuses his research on financial time series analysis. He uses high frequency data form foreign exchange markets to estimate volatility and forecast trends of the market.

Professor Dimitris Bertsimas has worked on combinatorial optimization, probabilistic analysis of combinatorial problems, stochastic and dynamic optimization and applications of or in the airline industry.

Professor Robert Freund has continued his research on new methods of linear programming that build upon the new algorithm developed by Narendra Karmarkar at AT&T Bell Laboratories.

Professor Thomas Magnanti has studied optimization models and algorithms for problems in communication system design, production management and distribution systems planning.

Professor Jeremy Shapiro has continued to work on a variety of applications of mathematical programming in manufacturing, logistics planning, and financial planning.

Professor James Orlin has worked on developing faster algorithms for problems in network optimization. he is interested in developing solution procedures (algorithms) that are demonstrably efficient, either in the worst case or the average case.

Information Technologies (formerly called Management Information Systems).
The increasingly widespread availability of information from numerous sources both within and external to organizations and the rapid changes in information technology poses significant opportunities and challenges to management. The Information Technologies Group addresses these issues by experimenting with new technologies such as expert systems and heterogeneous databases, by examining a variety of strategic information applications, and by studying underlying organizational issues.

Professor Geoffrey Brooke has examined the relationship between the slowing of productivity growth that has occurred in the U.S. since 1973 and investment in information technology. Professor Brooke continues to focus on the economic aspects of information technology, and is planning a study of information costs in complex organizations to discover and evaluate methods of reducing those costs and, thus, increase firm productivity.

Professor Erik Brynjolfsson focuses his research on the economic impacts of information technology, including organizational design and productivity. He has developed models of the relationship between information costs and the allocation of decision right within and among firms. His econometric work assesses some of these models and also estimates the impact of information technology on various measures of economic welfare.

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 and intra-organizational information exchange. A specific focus has been "context interchange" which deals with differing meanings between the source and the receiver. A prototype system, called CIS/TK, which currently integrates five disparate information systems has been developed by this group. Extensions to deal with rapidly changing semantics and identification of sources are being developed.

Professor Chris Kemerer has developed models to aid the management of software development and is developing and testing measures of software productivity. His most recent work focuses on metrics and models for evaluating object-oriented technologies.

Professor Wanda Orlikowski's research concerns the relationship between information technology and organizational change.

She has continued her research into the automation of systems development work, the role of electronic communication media and groupware in coordinating work, and the restructuring of organizations through information technology.

Professor Richard Wang has extended his work on the issue of "where is the data from?" in database management to address issues involved in developing Quality Data Base Management Systems (QDBMS). Professor Wang organized the first Workshop on Information Technologies and Systems (WITS) which served as the forum for the exchange of ideas by faculty and leading industry practitioners in the Information Systems field. and initiated the Total Data Quality Management (TDQM) Consortium with Professor Stuart Madnick.

Dr. John Rockart continues his work on critical success factors, systems development, and management of data resources. He is expanding his work on executive support systems downward into the organization as Management Support Systems and is exploring the use of information technology to manage interdependent organizations of a firm.

Dr. Jeffrey Meldman continues to track developments in the legal protection of information, particularly proprietary rights in software and personal rights of privacy.

Marketing

Professor John Little has focused much of his energy on "The Consumer Packaged Goods Project," an activity to understand the impact of large, single-source data sets. One focus of this project is in modeling advertising effects, that is, using laboratory experiments with extensive panels of households to understand how television exposures affect both brand choice and the size of packages bought by customers. Other foci are on how newspaper features affect store choice and how cents-off coupons affect profitability. John Little is also working on the development of some basic "laws of manufacturing,"

Professors John Hauser and Birger Wernerfelt are continuing a major effort on the profitability of customer-satisfaction programs. They are working with large manufacturing and service firms to design programs to measure customer satisfaction and innocent employees based on customer satisfaction in order to focus these firms on meeting customer needs. By understanding the tradeoffs between short-term and long-term effort, Professors Hauser and Wernerfelt hope to enable firms to look beyond current market share and current margins to build a profitable asset of satisfied customers.

In addition to his responsibilities as Editor-in-Chief of *Marketing Science,* Professor Hauser has continued his research on understanding the voice of the customer for use in new-product development. His research on this subject has lead to improved methods of data collection so that firms have better information on customer wants and needs.

Professors Hauser, Wernerfelt, and Urban have continued their research on the theories of how consumers seek information and value that information. By understanding better the process of information search, they hope to provide guidelines so that firms can provide such information profitably. This research is related to Professor Glen Urban's work on information acceleration, that is, the use of multimedia technology to provide tomorrow's information to consumers today. Information acceleration was applied to the forecast of 1994 alternative-fuel vehicles.

Professor Birger Wernerfelt has continued his research on how pricing systems are developed. For example, he has explored why in the United States consumers bargain with automobile dealers but in some European countries the price is taken as posted. Similarly, in Japan, the dealer comes to the consumer but in the United States the consumer comes to the dealer. He has completed papers on salespeople and brochures, on employees and independent contractors, and on alternative ways to govern trading relationships.

Professor William Qualls has used theories drawn from the behavioral sciences to describe and explain marketing management practices.

His most recent research activity has focused on the modeling of customer behavior via partial least-squares analysis. This estimation technology has been applied successfully to the service operations of a large automobile manufacturer.

Professor France LeClerc has continued her research into the image and image-related aspects of communication. She has studied first-hand how advertising agencies create advertising copy with the latest information technology. With John Little she has been studying the impact and the design of the different presentation characteristics of "free-standing inserts (FSIs)." FSIs are those inserts that you receive in your Sunday paper. They are a very effective promotional device.

Professor Wujin Chu's primary interests lie in the study of channels of distribution. One research theme is the interaction between manufacturers and their channel intermediaries under incomplete information.

Currently, he is looking at the impact of information technology and the widespread availability of market-research data on the balance of power between manufacturers and retailers. He is also examining the welfare implications of market practices. He hopes that his research will be one of the first formal analyses of ethical issues in marketing.

Professor Drazen Prelec has focused his activities on the contemporary research in consumer behavior that is influenced by economic models and psychological concepts and theories. He is examining several problem areas of individual decision-making, all basic to our understanding of human action which illustrate how economic intuition and psychological reality clash in an interesting and scientifically productive way.

Behavioral and Policy Sciences (BPS)

BPS is composed of faculty groups who focus on four broad areas of concern to organizations. They are: (1) Organizational Change and Development; (2) Organizational Responses to and for Employees; (3) Technology and Innovation; (4) Strategy and a Global Business World. The faculty in the BPS area come from a variety of discipline backgrounds, such as economics, behavioral science, sociology, anthropology, finance, control systems, and operations research. Collectively they represent a set of faculty who are interested in developing and testing theory and methodologies that will be useful to organizations around the world as they come to grips with issues in our four central areas of interest.

There is some urgency in all of this as our belief is that the business world is experiencing an unusual degree of turbulence relative to the last thirty or forty years and that this is likely to continue at least the same pace for some years to come. This challenges all business schools and Sloan is responding. Within Sloan the BPS group is perhaps the one most directly affected by this turbulence and the emergence of new organizational forms. Thus we are being challenged by our environment and have been responding by rethinking our teaching curriculum and the content of our research.

Teaching Curriculum. The BPS group plays a major role in all the teaching activities of the School. The Sloan Masters Program is at the teaching heart of the School and we have been active in the redesign of the core where we will have two entirely new and redesigned core courses. One is a new "Perspectives" course which is being developed by a committee chaired by Bob McKersie and Deborah Ancona. The second is a core course in strategy.

The group offers 65 electives to a total enrollment of 1,913 students. These courses undergo continuous renewal as they reflect the faculty's emerging research interests. With the School's mission focusing on a global world, technology and change, it is a major challenge to the BPS group to produce a dynamic, relevant, set of courses for the students, as the 40 faculty in BPS are doing work central to these areas. Although the core courses redesign is not scheduled until the 92/93 academic year, several new or substantially revised, Masters electives were tested successfully this year. Among these were:

15.970: Technology Module (Master's Core) (Tyre, Henderson, Eppinger, Ulrich)

15.962: Business Government Relations in Western Europe (Ziegler)

15.938: Economics for Technology Strategy (Henderson)

15.365: The Manufacturing/Technology Interface (Utterback)

15.363: Managing Technology Change in Manufacturing (Tyre)

15.674: International Perspectives on Industrial Relations and Human Resource Development (Lynch)

15.314: Organization Structure and Design (Thomas)

There was also considerable curriculum redesign of some BPS courses in the MOT, Leaders for Manufacturing, and Ph.D. Programs. An illustrative example would be Bob Thomas' work with the Leaders for Manufacturing. His "Leadership and Organizational Change" course had the students design a pair of assignments that they would undertake during their internship. To quote from Prof. Thomas "One assignment required them to do an organizational diagnosis -- i.e. to identify a persistent problem in their organization and, through intense study, come up with a causal analysis of its roots -- and to suggest a change plan for resolving the problem. Without a doubt, these papers were by far the best analysis I have ever received from a group of Masters students -- they proved to the students the importance of organizational theory for understanding and responding to organizational problems."

This kind of teaching innovation which gets the students directly involved and crosses more than one, apparently separate, course is an example of the kind of innovation being tried in several places within BPS and between BPS and the other two groups in the School.

Having a vibrant successful set of course offerings which leaves the students well prepared for a changing future is one of the tasks being tackled by the BPS group.

Research Activity. The other task is to focus our considerable research activity onto areas of central concern to organizations as they look forward to the future. This has occurred in a number of ways during this last year. As research is our heritage the initiatives and projects make a long, long list. Most of the six research faculty had either Ph.D. or Masters students intimately involved in their research and were typically engaged in two to four research questions. These are described in detail in the individual faculty reports but for the purposes of this report a flavor can be gained by picking one example from each of the four areas of our interest.

(1) **Organizational Change and Development.**
The new organizational learning center is concerned with both organizational change and with understanding how organizations learn, general properties, in one sense, of organizational transformation. This central question of transformation and continuous learning is not one that will yield to quick simple solutions but is one that is central to successful organizations of the future. With this in mind we hope to press on vigorously to seek theory and empirics of real to help organizations.

(2) **Organizational Responses to and for Employee.**
With the enormous decline of unions in America and comparable changes in much of the western world some new forms of organization/employee relationships are emerging. To understand these, and their Policy implications, is clearly important. This requires nothing less than to step back and rethink the important central tenants of what kinds of organizations we can expect to see and what does that imply, (given changing employee expectations) for an organization's human resource policies and practices. This is a new, complex, and as yet embryonic movement but it is one that is central to an organization's "next century" competitiveness.

(3) **Strategy and a Global Business World.**
As the nation state is forced to deal with quasi-trading blocks, and as individual companies manufacture and sell globally, the nature of competition for all organizations changes. Organization theory for the multi-national firm is embryonic at best and our understanding about the relationship between public policy and the firm in an era of global competition is quite inadequate. The group's strong prior research in Europe and Japan together with their work in corporate strategy is proving to be a useful base for this new research. Active involvement in the Nanyang project in Singapore and the RI project in Italy have extended our research network.

(4) **Technology and Innovation.**
All of the four interest groups within BPS interact with all the rest (and the rest of the School). However, this interest area has perhaps the highest level of mutual interaction. All six professors are working on aspects of technology, innovation and the diffusion of these. However, the International Center for the Research on the Management of Technology (ICRMOT) is the embodiment of one kind of research program we find effective and would like to maintain.

The research seminars, field sites and interaction with sponsors are a constant source of new insights and data. As this flow of work (for example over 27 working papers this year)has begun to influence the behavior of companies and our research colleagues at other universities, it becomes clear that the BPS group's influence can be considerable.

The research areas we have chosen are complex, broad, and difficult. They are, however, central and they will be with us for a long time. We are cognizant of the enormous difficulties but also of the centrality of the questions. We intend to persevere and contribute what we can to building knowledge that individuals and organizations will find useful.

Communication. Professor JoAnne Yates was on leave to pursue her new projects on the history of information handling in firms during the twentieth century, spending the spring term as a Senior Research Fellow at the Hagley Museum and Library in Wilmington, Delaware. During the year she wrote and presented several papers on her historical research, some to be published in edited volumes and proceedings. She also continued to pursue her joint research with Professor Wanda Orlikowski (from Sloan's Information Technology group) on genre in electronic communication. A paper from this research appeared in the Academy of Management Review this year and another is in progress.

This year Visiting Professor Jolene Galagher coordinated the Sloan Communication Program in the absence of Professor Yates. Her research focuses on the use of advanced information technologies to support communication and collaboration in the production of intellectual products such as research reports. Her papers have appeared in Human-Computer Interaction and Information Systems Research, as well as in edited volumes and proceedings.

Lecturers David Breakstone and Lori Breslow pursue interests in health communication and mass communication. Lecturer David Breakstone wrote a monograph on low back pain for the Harvard Health Letter and copy-edited a collections of essays on mental health, racism, and sexism. Lecturer Lori Breslow produced and wrote a film of health care proxy law, "Who Will Speak for You?" IN addition, The Social Impact of the Mass Media, a book she co-edited, came out this year.

LEADERS FOR MANUFACTURING PROGRAM
The program is transitioning from its experimental phase to self-sustainability and expansion. LFM is halfway to its goal of recruiting four more partner companies, as Intel Corporation and Ford Motor Company joined during the first half of 1992. LFM partner company representatives have been closely involved throughout the sustainability efforts. Another move toward self-sustainability involves student support: the goal is for less student support to be required from the program eventually. The past year's classes of nonsponsored fellows were granted a monthly stipend (first-year students) and research assistantships (second-year students) with the written expectation that they would join a manufacturing firm upon graduation.

(The Leaders Program has also been awarding *all* fellows' tuition, regardless of company sponsorship.) The program this year is offering financial aid for tuition and stipend as loans that are forgivable if the students join a United States manufacturing firm at graduation and continue working in manufacturing for the next four years; students' loans are combined with research assistantships during their second year. The long-term plan is for up to half of the LFM fellows each year to receive tuition and stipend support directly through the partner companies' sponsor programs.. During fiscal year 1992, eight LFM fellows were funded by sources outside the Leaders Program and its partner companies (e.g., Robert N. Noyce, National Science Foundation, and National Consortium for Graduate Degrees for Minorities in Engineering and Science, Inc., fellowships).

The LFM total quality management emphasis has inspired MIT to participate in industry's "TQM University Challenge": a challenge to universities to integrate TQM principles and concepts into management and engineering curricula and the universities' administrative processes. The Institute's proposal for meeting the challenge, generated by Professors Thomas Magnanti and Stephen Graves with LFM staff assistance, was accepted this past year. MIT is now working on the challenge together with IBM, one of five companies hosting universities through the Challenge program.

The Institute's Challenge program, expected during the early phase to involve up to 75 Institute faculty and administrators at all levels, is headed by Magnanti; Professors Graves and John Heywood also serve on the Challenge steering committee. (David Wormley, who was originally on the committee, is now dean at Pennsylvania State University's College of Engineering.)

Graduates

This past June, 34 LFM fellows graduated; the final thesis is nearing completion for a September 1992 graduation, bringing the total to 87 graduates of the Leaders Fellows Program. By June 1992, of the 34 fellows graduating that spring who had confirmed their future plans, 76 percent had taken positions in Leaders partner companies and 15 percent had joined other manufacturing companies, choosing from an average of 3.2 job offers. Only one student accepted a consulting position.

LFM Fellows Program graduates are proving effective in industry. One, as superintendent of an International Paper finishing operation responsible for scheduling, distribution, and production, supervises 25 salaried employees and 175 hourly workers on three shifts. In two years, he has been instrumental in consolidating two facilities into one, relocating over a million pounds of finished goods inventory without missing a shipping day. Another has worked in a management team to reduce some lot sizes by as much as 80 percent. A third, supervising thirty manufacturing line workers at a General Motors chassis facility, has been instrumental in reducing scrap from $109,000 over budget per month to $4,000 per month savings to budget.

The Fellows' class size has increased from 20 members in 1988 to 45; this year, 18 percent of the applicants were accepted. Those admitted in 1992 (Class of '94) offer an average of 3.8 years of full-time work experience, with a range of up to 9.5 years. Forty percent of the Class of '94 have work experience in the LFM partner companies; 27 percent of the class are company-sponsored, and almost one quarter are women and underrepresented minority students.

Of approximately 70 students supported by the Leaders Program this year in more traditional graduate-degree programs, 14 earned master's degrees and six earned doctoral degrees during the past year.

Faculty and Curricula

The Leaders Program closely involves 50 faculty in many disciplines, actively encouraging work across disciplinary boundaries and supporting 34 engineering and twenty-one management faculty to visit partner firms. Fifteen serve as "coordinating liaisons" with partner companies, becoming well versed in their company's organization, culture, products, technologies, challenges, and needs to facilitate working relationships with the program. The companies have also selected 12 faculty "research liaisons" with whom they are conducting cooperative research.

Four junior faculty and one senior faculty who have been involved with the Leaders Program were promoted this year; tenure was granted another two junior faculty.

A "manufacturing engineering core" that codifies basic manufacturing principles from an engineering standpoint is evolving from the participating engineering departments' diverse requirements, emphasizing engineering strength in manufacturing and related disciplines. Increasingly popular among the LFM fellows, the core includes a processes course (e.g., 3.52J Materials Processing, 2.810 Fundamentals of Manufacturing Processes), the multidisciplinary 2.739J Product Design & Manufacturing course, the two summer courses of 2.851J Systems Optimization & Analysis for Manufacturing and 3.81J Engineering Probability & Statistics, and two departmental electives. An Alfred P. Sloan Foundation grant helps fund the core development.

This past year, 15.515 Financial & Managerial Accounting was introduced to the LFM Fellows Program summer curriculum. The 2.739J Product Design & Manufacturing and 2.810 Fundamentals of Manufacturing Processes courses were further modified (both supported by the Sloan Foundation to better meet LFM needs).

The 15.810 Introduction to Marketing course that the fellows take with other Sloan students was also changed to emphasize quality function deployment, and 3.81J Engineering Probability and Statistics was modified to emphasize applications to quality control and process improvement. The 3.52J Materials Processing course attracted significant numbers of LFM fellows for the first time this past year.

Research
The LFM Research Program funds 34 projects, supporting work in most of Sloan's disciplinary groups ranging from technological innovation to human resource management. The list of LFM working papers now includes almost 250 documents, including 88 preprints, 48 published papers, 87 LFM fellows' theses, 19 other SM theses, and two Ph.D. theses covering a wide range of research topics.

Dr. Ashraf Alkhairy worked closely with the partner companies to test his method for optimizing product and manufacturing process parameters. Several projects indicated his method to be broadly applicable, statistically rigorous, robust against false conclusions, and efficient. One required 16 experiments using the Alkhairy method compared to 64 using the Taguchi method. The recommendations implemented have improved product strength 30 percent, saving the company $300,000 per year; doubled production capacity, saving $500,000 in capital investment; and enabled the company to broaden its product line.

In October 1991, the program hosted a symposium at MIT to tap the insight and experience of partner company practitioners. The interest generated among the 400 attendees was so strong that several subgroups formed during the symposium are still meeting. More symposia have been planned. LFM also co-sponsored with Stanford University and the Sloan Foundation the 1992 Operations Management Workshop, bringing together faculty from leading business and engineering schools and several leading industry practitioners. Two days were allotted to recent operations management research, two days to curriculum and career development in design and manufacturing.

COMPUTER CENTER
Major efforts were made during fiscal year 1992 to:

- increase troubleshooting support for faculty and staff
- integrate computers into the Sloan Senior Executive program
- begin the development and support for administrative systems at Sloan
- improve the appearance of the computer facility

Significant improvements were made to student labs New labs were opened to facilitate PC and Macintosh group work and faster hardware was purchased in response to student needs. A color scanner was added to the PC lab. The entire computer facility was painted, and new computer tables and chairs were purchased. Major improvements were made to the air conditioning systems.

Converting an existing position to full-time word processing support, increased hours of student lab support and the recommendation of Microsoft software for incoming students resulted in much improved student, staff and faculty support.

For the first time, the Senior Executive Program provided PC laptops to all students in the spring 1992 program, and computer training and support was increased. Computer components continue to be added to the program.

Macs in the Masters Program Office and PCs in the Management of Technology Office are being networked. ASD is developing an admissions system for the Masters office, and the Executive Education Office is pilot testing an enrollment management system from The Exeter Group.

Hardware and software grants totaled approximately $225,000. Hewlett Packard donated six workstations to student labs. Microsoft and Apple donated software and Bloomberg Financial Services donated a Bloomberg terminal for access to financial data.

Affirmative Action
The School continues to seek under-represented minorities and women for faculty positions and to take actions to retain these faculty. In this past year we have granted an endowed professorship for the first time to a senior woman faculty member. We also promoted a female senior lecturer to a tenure-track position at the rank of associate professor, and added a female assistant professor in human resource management

Nine percent of our Sloan Fellows were women, two percent minorities, and in the Management of Technology program, five percent were women. Our Masters program was comprised of 20% percent women, 11% minorities. Our ability to attract minorities is most difficult in the Doctoral program; this year 18% were women, 3% were minorities.

We were able to maintain the same level of fellowship support to minorities as last year, which was an increase over years prior to 1990. We continue to look for ways to improve our ability to attract individuals from under-represented minority groups.

Personnel Changes
The School appointed two faculty to professorships: Professor Lotte Bailyn was named to the newly endowed T. Wilson (1953) Professorship in Management. Professor Bailyn's work focuses on the relationship between work/career and family. Professor Chi-fu Huang was appointed J. C Penney Professor of Management. Professor Huang's research is in the area of financial economics and dynamic general equilibrium theory.

One faculty member was promoted to Professor: Professor Paul Osterman, received his Ph.D. in Economics and in Urban Studies and Planning from MIT in 1976. His principal fields are Labor Economics, Human Resource Development, Employment Policy and Economic Development.

Five faculty were granted tenure: K. Paul Asquith, received his Ph.D. in Economics from the University of Chicago in 1980. Professor Asquith is best known for his work in Corporate Finance, Corporate Control, and Capital Markets; Charles H. Fine, received his Ph.D. in Business Administration from Stanford University in 1981. Professor Fine specializes in Operations Management, Management Technology Evaluation, Quality Management and Dynamic Process Improvement; Kenneth A. Froot, received his Ph.D. in Economics from the University of California Berkeley in 1986. Professor Froot specializes in International Finance, Economics and Econometrics; David Scharfstein, received his Ph.D. in Economics from MIT in 1986. Professor Scharfstein's research interests are in Corporate Finance, Economics of Corporate and Securities Law and Theory of the Firm; Jeremy C. Stein, received his Ph.D. in Economics from MIT in 1986. Professor Stein's research has been in the area of option theory and the modeling of corporate behavior.

Three faculty were promoted to Associate Professor: Professor Michael A. Cusumano, received his Ph.D. in Japanese History and East Asian Languages from Harvard University in 1984. Professor Cusumano's interests lay in Corporate Strategy and International Competition, Management of Technology, Comparative Business History (Japan, United States), Production/Operation Management; Professor Lawrence M. Wein, received his Ph.D. in Operations Research from Stanford University in 1988. Professor Wein specializes in Operations Research, Operations Management, Queuing Theory, and Stochastic Control. Professor JoAnne Yates, received her Ph.D. in English from the University of California in 1980. Professor Yates had previously been a Senior Lecturer in Management Communication and her research interests include Business History, Communication and Information Technology.

New faculty in 1991-92 included Associate Professor Drazen Prelec who holds a Ph.D. in Experimental Psychology from Harvard University in 1983; Assistant Professors: Geoffrey Mark Brooke who received a Ph.D. in Management Information Systems from the University of Minnesota in 1991; Maureen A. Scully holds a Ph.D. in Organizational Behavior from Stanford University in 1990; and Bin Zhou received a Ph.D. in Statistics from the University of California, Berkeley in 1991.

Other new academic staff included Lori Breslow from Boston University teaches communications for managers; Christopher Athaide, from MIT, taught Introduction to Management Science; Stan Finkelstein, from MIT, conducted research and teaching on the pharmaceutical industry.

The School had a number of visitors, faculty and lecturers: Michael Magazine from the University of Waterloo taught Operations Research; Ella L. Bell from the University of Massachusetts taught Managerial Behavior; Janice A. Klein from Harvard University taught Operations Management; Alfred A. Marcus from the University of Minnesota School of Management taught in the Corporate Strategy and Policy; James F. Gammill, Independent consultant, formerly at the Harvard Business School, taught Finance ; Connie P. Ozawa from the Harvard Law School taught Corporate Strategy and Policy; Robin A. Prager from the Owen Graduate School of Management (Vanderbilt University) taught Economics; Robert Wade, Development Political Scientist/Economist/Anthropologist from the United Kingdom taught International Business Management and Asia in the World Economy; David K. Goldstein, from Boston University taught Management Information Systems; Thomas A. Barocci, President of TAB Associates, Inc. taught Industrial Relations and Human Resource Management; Lewis M. Rambo, from Arthur D. Little, Inc. gave a series of lectures in Industrial Relations and Human Resource Management.

Seven faculty were on sabbatical leave including Professors John Carroll, Charles H. Fine, Robert M. Freund, Henry D. Jacoby, Thomas A. Kochan, Thomas W. Malone, John E. Van Maanen

Faculty on other leaves included Professors Kenneth Froot and Nancy L. Rose.

Returning from leave were Professors Lotte Bailyn, Chi-fu Huang, Robert McKersie, Michael Scott Morton, Richard Schmalensee.

It is with great sadness that we report the death of Professor Emeritus Daniel M. Holland who provided invaluable service to the Sloan School for many years in the Finance area of our Economics, Finance and Accounting group.

Within the Administrative Staff, the changes are as follows:

New appointments: Ellen L. Baum, Lisa Kaminski and Junco Norton have joined the Finance and Administration office as Financial Analysts; Linda Carter, Director of Masters Alumni/ae Relations; Anne Detweiler, circulation Manager with the Sloan Management Review; Lori Correale, Assistant Director of Development/Director of Annual Funds; Colin MacLaurin, Assistant Director of Sloan School Resource Development; Margaret Scoppa joined the Behavioral and Policy Sciences group as Area Administrator; Leonard J. Hausman became Director of the Taiwan Program; Louise I. Barteau from support staff to Coordinator, Masters Program; Lucinda M. Hill to Associate Director of the Masters Program; Kimberly Miner of the Sloan Management Review departed; Norma Gicka, Accounting Analyst for the Finance and Administration area retired after 13 years of service.

EXTERNAL RELATIONS

Resource Development The Sloan School's FY92 income was $8,941,006 a good year considering that this was the wind down of MIT's *Capital Campaign.* Also, last year's all time record of $12,362,929 reflected a large $4,000,000 gift from Taiwan's Epoch Foundation and a one time payment, up front, of $1,500,000 gift from Sanwa Bank for International Curriculum Development. FY91 and FY92 comparisons are listed below.

Current	Y91 Total	FY92 Total
Unrestricted	551,844	752,908
Fellowships	128,110	139,251
Chairs	-	-
Restricted Resch.	3,100,005	1,348,350
Restricted Resch. Sys. Dyn.	1,238,164	763,731
Res. Patrons	-	-
Other	112,669	2,073,625
Total Current	$5,130,792	$5,077,865
Endowment		
Unrestricted	39,595	40,239
Fellowships	550,411	471,778
Chairs	1,137,131	1,351,124
Restricted Resch.	-	-
Res. Patrons	-	-
Other	5,505,000*	2,000,000
Total Endowment	$7,232,137	$3,863,141
Grand Total	$12,362,929	$8,941,006

Notable among FY92 gifts was a bequest of $225,000 from former Dean E. Pennell Brooks' Estate. Dean Brooks played a significant role in the initial development of the Sloan School when he served as Dean from 1952-1959. We received two $300,000 pledge payments towards full professorships, one from John Norris Maguire GM'60 and the other from J. Spencer Standish '45MG. It also should be noted that Thomas P. Gerrity GM'63 followed through on his earlier pledge which was made before he became Dean of the University of Pennsylvania, Wharton School, our competitor. Dean Gerrity made a $130,000 gift of stock which was designated for unrestricted use. Chairman of the Sloan School Governing Board, DuWayne J. Peterson '55MG also made a $126,563 payment on his pledge towards doctoral fellowships. $4,000,000 Epoch Foundation (Taiwan); $1,500,000 Sanwa Bank.

Other significant revenue, other than from individual sources, included another $2,000,000 gift from the Epoch Foundation in Taiwan and $2,000,000 from Nanyang Technological University in Singapore. Along with last year's contribution of $1,500,000 from Sanwa Bank for International Curriculum Development, these funds will help Sloan expand its international programs particularly its Asia Pacific Initiative. Finally, we received a $600,000 pledge and a $150,000 pledge payment from Credit Suisse. This gift was designated to a critical area of need in the Sloan School doctoral fellowships.

The Sloan School, in anticipation of the wind down of the *Campaign,* has begun to put an emphasis on increasing the percentage of alumni/ae who give to the Sloan School and we are focusing on small and medium size gifts from Sloan's alumni/ae body. We have now hired a full time Annual Fund Director and we have hired a full time Master's Alumni Relations Director which will allow us to begin to organize class gifts and develop a reunion giving program.

As these programs begin to take shape, the school will have a better foundation on which to plan for the next capital campaign.

LESTER THUROW

SCHOOL OF SCIENCE

Introduction

This is my first Report to the President since becoming Dean of Science. I would like to take this opportunity to acknowledge the outstanding leadership which my predecessor, Dean Gene Brown, provided during his six years as Dean of Science. I feel very fortunate to have inherited a school which is replete with vigorous activity on both the educational and research fronts. I also inherited from Gene an excellent group of laboratory and department heads as well as a superb supporting staff.

There has been some turn-over in the School of Science headquarters staff. Both I and the School feel very fortunate to have retained the services of Ms. Evelyn Pérez as Assistant Dean for Personnel. Ms. Donna Ticchi has joined us as Assistant Dean for Financial Administration, Ms. Priti Patel as Senior Staff Assistant and Ms. Elizabeth McCaffery as Administrative Secretary. In addition, Ms. Sarah Carothers has joined us as the first Director of Development appointed in the School of Science. We have also been pleased this past year to welcome Prof. Stanley Kowalski as director of the Bates Linear Accelerator Center and Prof. Robert Redwine as the director of the Laboratory for Nuclear Science. Finally, Prof. Ernie Moniz has succeeded me as Head of Physics.

The quality of an academic enterprise such as the School of Science is determined primarily by the caliber of the faculty that make it up. Thus, one of my highest priorities as dean is to insure that we both hire and promote truly outstanding educators and researchers. In the past year, seven School of Science faculty were promoted to tenure. We have, in addition, hired sixteen new faculty, two senior and fourteen junior. The two senior faculty are already world leaders in their fields. All fourteen of the junior faculty emerged from exhaustive searches as being among the most promising young scientists of their generation. We are, of course, hopeful that they will fulfill their promise as teachers and as researchers here at MIT. This, in turn, means that we must provide a nurturing environment which is optimal for their development.

One of the hallmarks of Gene Brown as Dean of Science was his adamant insistence on quality education. As a result, I believe that our teaching in the School of Science, most especially in the core courses, is genuinely excellent. The caliber of our performance in education is perhaps best illustrated by the fact that four out of the six founding MacVicar Teaching Fellows, Dan Kemp, Arthur Mattuck, John Southard and Graham Walker, are from the School of Science. It is my intention to continue Gene's tradition with special emphasis on the core courses. I anticipate that the core courses will evolve significantly both in content and in method of presentation over the next several years. Of course, in 1993 we will also introduce Biology as part of the core. Here, once more, MIT and the School of Science are acting as leaders for the nation. A second major new program which will be introduced shortly is that of Minors in Science. After exhaustive study, the departments have constructed Minors programs in each of their respective disciplines We take special pleasure in the fact that this program was initially suggested by two undergraduate students, Christie Halle and Barbara Manganis.

There is a large number of issues which the School of Science must address and resolve over the next several years. First the elimination of retirement by age in Dec. 1993 could change the demography of MIT significantly. However, we do not know in advance how severe the actual problems will be and most predictions are pure speculation. Accordingly, we are still trying to develop appropriate strategies. On the one hand, we must be able to hire new faculty and to provide them with appropriate laboratory and office space. On the other hand, we must maintain an environment such that our faculty can have fulfilling and productive careers as long as they are able. There are no easy answers to this dilemma.

Another general issue which must be addressed is that of the research ladder. It is clear that the research staff are essential to the health and vitality of the research enterprise at MIT. The current career system for the research staff has many positive features but it also has a number of weaknesses. Questions include whether or not there is appropriate career mobility on the research ladder and what privileges accrue at each stage. We also need to review carefully the role of the research staff in undergraduate and graduate education as well as their relationships with the academic departments.

The School of Science is severely affected by policies of the federal government with respect to research funding in general and graduate student support, in particular. We take great pride in the fact that our constituent departments typically educate among the largest numbers as well as the highest quality PhD's in their respective fields in the United States. Thus, we play a central role in the long term health of the scientific enterprise in this nation. At that same time, the cost of graduate education is spiraling upwards while the available resources are progressively more constrained. Clearly, we must help our national leaders understand this dilemma and thereby work towards revitalizing the government–university partnership which has been so important to this nation's economic and social welfare.

One of the issues which is most difficult to resolve but which, especially in our increasingly heterogeneous environment is most important to address, is that of "good behavior." This includes ethical conduct in professional, scientific matters as well as interpersonal relationships. In this past year we established a committee chaired by Prof. Paul Schimmel entitled the Committee on "Education Programs on Research Protocol." The Schimmel committee has made a number of specific recommendations which we hope to implement over the next year. However, new, creative ideas are still very much needed in this arena. Clearly, we must eliminate harassment and discrimination completely from MIT and we must maintain an environment in which people always behave ethically in their professional endeavors.

Finally, many of the goals discussed above cannot be achieved without adequate financial resources. As I mentioned at the beginning of this report, Sarah Carothers has joined us as Director of Development. We are planning many initiatives in the development arena which we hope will lead to new chairs in the School of Science, a significant endowed fund for junior faculty research support, graduate student fellowships and many other new capabilities.

ACADEMIC PROGRAMS

There were 730 undergraduates in the School of Science during the past academic year, a slight increase from the previous year. The number of minority students at the undergraduate level changed as follows:

Blacks	Decreased from 26 to 20 (23.08% decrease)
Hispanics	Increased from 30 to 39 (30% increase)
Native Americans	Remained at 2 (0% increase)
Asian Americans	Increased from 137 to 160 (16.79% increase)

The female undergraduate population increased from 272 to 281 (3.31%). Twenty-two percent of the Institute's upperclass undergraduates were enrolled in the School of Science.

Graduate enrollments in science decreased from 1,069 to 1,045. 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	Increased from 8 to 9 (12.50% increase)
Hispanics	Decreased from 10 to 9 (10% decrease)
Native Americans	Remained at 0 (0% increase)
Asian Americans	Increased from 27 to 29 (7.41% increase)

The number of female graduate students increased from 256 to 262 (2.34%).

There were 253 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'92 volume of research was slightly over $99 million.

ROBERT J. BIRGENEAU

Department of Biology

INTRODUCTION

The Biology Department currently has 51 active faculty members of whom 13 are located in the Whitehead Institute, ten are located in the Center for Cancer Research, three are joint appointees with the Department of Brain and Cognitive Sciences and one is joint with Chemistry. Two of the faculty are Nobel laureates, 18 are members of the National Academy of Sciences and eight are investigators of the Howard Hughes Medical Institute. The Department has a very strong international reputation in research and teaching and has been a leading contributor to the development and application of molecular biology. Those research groups not located in the Whitehead Institute or Cancer Center will be moving to a new Biology building which recently began construction and is expected to be occupied late in 1993.

EDUCATIONAL ACTIVITIES

Undergraduate Program

In the past year, the maximum number of undergraduates registered as Biology majors was 264. Of these, 80 received the degree of Bachelor of Sciences in Biology: 61 in the regular Course VII Program, 19 in the VII-A Program. The recipient of the John L. Asinari Award for outstanding research by undergraduates in Biology for 1991-1992 was Lisa Arel, working in the laboratory of Professor Ronald McKay in the Departments of Brain and Cognitive Sciences and Biology. The Department is proud that four of its faculty were recognized for their roles in undergraduate education. Dr. Graham Walker was named a MacVicar Faculty Fellow. Dr. Eric Lander won the Baker Award for his teaching in 7.012 and Drs. Richard Mulligan and David Housman were named co-recipients of the Science Council Teaching Prize for their efforts in creating and teaching the biotechnology project laboratory.

Fifty-six percent of our majors are women and 4% are underrepresented minorities.

The incoming class of the fall of 1993 will be required to take a General Institute Requirement in Biology. This requirement is an exciting opportunity for the Department to strengthen the knowledge of all of MIT's students in modern biology. This experience should nucleate an increasing level of interest in biological processes and materials in other departments and enrich the total MIT community. There are many challenges in teaching approximately a thousand students each year a new course. It is anticipated that at least three different courses (all versions of the General Institute Requirement, 7.01) will have to be taught each year. Each of these courses will be the responsibility of two faculty and some of the best lecturers in the Department are assigned to this task. All of the students will also be required to attend recitation sections that will be smaller than 30 students. This will provide a more conversational setting for reviewing the lecture material and working through examples of problems. The curriculum must span from the fundamentals of molecular and cell biology to the exciting recent developments in biotechnology and human genetics. Each course will have different emphasis dependent upon the interest and expertise of the faculty. Some lectures will undoubtedly cover questions such as the practicality of gene therapy for the treatment of human diseases and the nature of genes which encode functions in the brain necessary for long and short term memory. Along with discussions of advances in biological science, questions of the ethical use of this newfound knowledge will be debated.

Graduate Program

During the period from July 1, 1991 to June 30, 1992, 21 Ph.D. degrees and one Master's degree were awarded in the Department; one Ph.D. degree was 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 1991-1992 was 185, with another 21 in the Joint Program. The entering class in 1991, including 6 in the Joint Program, was 36. The class arriving in September, 1992 will be 29, including 9 WHOI students.

One new subject was added to the graduate curriculum this past year, 7.87 X-ray crystallography of proteins and nucleic acids. This subject is offered by Professor Carl Pabo to strengthen our offerings in structural biology.

RESEARCH

The research activities of the Department are in the areas of biochemistry, genetics, microbiology, cell and developmental biology, immunology, neurobiology, and virology. Research projects are described in the annual publication, *Department of Biology Annual Report,* available in the Biology Headquarters Office (56-511). The FY92 total direct cost of research in the department (including the Cancer Center and the Whitehead Institute) was $31.6 million ($12 million of that was in the Whitehead). MIT overhead on the funding in the department and the Cancer Center was $8 million. At a time of difficult research funding, the department has maintained its level of federal support. In addition to faculty and students, 275 Postdoctoral Associates and Fellows perform research in the various laboratories of the department.

PERSONNEL

Professors Alan Grossman, Arthur Lander, Ruth Lehmann, Terry Orr-Weaver, David Page and Hermann Steller were promoted to Associate Professor effective July 1, 1992. Professor Peter Kim has been promoted to Associate Professor and to tenure effective July 1, 1992, and Professor Paul Matsudaira has also been promoted to tenure.

We are pleased to report that four new faculty members have accepted positions in the Department:

Dr. Tyler Jacks joined the Department and the Center for Cancer Research as Assistant Professor on May 1, 1992. Professor Jacks is a developmental biologist who focuses on tumor suppressor genes in the mouse. He obtained his B.S. in molecular biology from Harvard University in 1983 and the Ph.D. in Molecular Virology from the University of California, San Francisco, in 1988. He was a Postdoctoral Fellow in the Whitehead Institute for Biomedical Research.

Dr. Jun Liu has also accepted a position as Assistant Professor joint with the Department and the Center for Cancer Research and will begin his appointment during the next year. His major research interests are in the areas of biological catalysis and organic ligand-receptor interactions in the context of developmental biology and immunology. Dr. Liu received the B.S. in Chemistry from Nanjing University in 1983, the M.S. in Chemistry from The Ohio State University in 1986, and the Ph.D. in Biochemistry from MIT in 1990. He has been a Postdoctoral Fellow in the laboratory of Professor Stuart Schreiber in the Department of Chemistry at Harvard University since 1990.

Dr. Hidde Ploegh will join the Department and the Center for Cancer Research as a Full Professor on July 1, 1992. Professor Ploegh's research interests focus on the organization and functional properties of the immune system. He studies the cellular mechanisms by which antigens are processed and presented to the immune system. He has made major contributions to the current understanding of the pathway by which peptides bind to and stabilize major histocompatibility (MHC) receptors in and on antigen-presenting cells. It is the complex of peptide antigen and MHC which is recognized by the T-cell receptor on the responding immune cell. This is one of the most exciting areas in cellular immunology and Ploegh is recognized as one of the leaders in this field. Dr. Ploegh received the B.S. in 1975 and the M.S. in 1977 from the University of Groningen and the Ph.D. in 1980 and 1981 from Harvard University and the University of Leiden.

Dr. Peter Sorger has accepted a position as Assistant Professor in the Department but plans to delay his arrival until the 1993-1994 year. Dr. Sorger will bring expertise in biochemistry, genetics and molecular biology to the Department. He is interested in the mechanisms that regulate cell division in eukaryotes and ensure the orderly progression of successive cell cycle events. Dr. Sorger received the A.B. in Biochemistry from Harvard University in 1984 and the Ph.D. in 1988 from Cambridge University. He is currently a Postdoctoral Fellow at the University of California, San Francisco.

Professor Gobind Khorana retired June 30, 1992. Professor Khorana received a Nobel Prize for the contributions of his research to the elucidation of the nature of the genetic code. His laboratory was the first to chemically synthesize a gene and thus helped establish the biotechnology revolution. More recently, Professor Khorana has studied the process by which photoreceptors transmit signals across cell membranes. We are pleased that he plans to maintain an active research laboratory in the Department.

Professor David Baltimore, who was a Professor of Biology at MIT and the founding Director of the Whitehead Institute for Biomedical Research before assuming the Presidency of Rockefeller University plans to return to MIT in the Spring of 1994. Professor Baltimore received the Nobel Prize for his contribution to the discovery of reverse transcriptase, the key enzyme in the replication of retroviruses such as HIV, the virus that causes AIDS, and he will continue his exciting research on AIDS and immunology in the new building for Biology.

Three faculty members left the Department at the end of this year. Professor Donald Rio accepted a position at the University of California at Berkeley, Professor Earl Ruley accepted a position at Vanderbilt University, and Professor Alexander Varshavsky accepted a position at the California Institute of Technology. We wish them well in their new careers.

Honors and Awards to the Faculty

It is a pleasure to report the following honors and awards to Biology faculty during the past year:

David Housman and Richard Mulligan were named co-recipients of the Science Council Teaching Prize for their teaching in 7.16.
Chris Kaiser and Hazel Sive both received Searle Scholar Awards.
Jonathan King was elected a Councillor of the Biophysical Society.
Eric Lander received this year's winner of the Baker Award for his teaching in 7.012
Carl Pabo received the Pfizer Award in Enzyme Chemistry for 1992.
Phillips Robbins was elected to the Institute of Medicine.
Paul Schimmel received the John D. MacArthur Professorship.
Phillip Sharp was named the first holder of Salvador E. Luria Professorship.
Joanne Stubbe was elected to National Academy of Sciences.
Graham Walker was named a MacVicar Faculty Fellow.
Robert Weinberg received Gairdner Foundation International Award 1992 (shared with Bert Vogelstein) for elucidating genetic events leading to the development of cancer.

OTHER

The Department of Biology is proud of the establishment of two new Chairs. The Ivan R. Cottrell estate established a Professorship in Immunology, and funds derived from the license of technology to Immulogic and a gift from Repligen established the Salvador E. Luria Chair. These resources will enrich scholarship in the Department of Biology and we are appreciative.

PHILLIP A. SHARP

Department of Chemistry

INTRODUCTION

The Department of Chemistry continues to be one of the leading academic centers of chemical science in the United States, with educational and research programs covering all the major areas of chemistry. In the 1991/92 academic year, there were 33 faculty, 84 postdoctoral researchers, 239 graduate students, 101 undergraduate majors, and 50 staff members actively involved in departmental programs. Research support continues to be strong, with approximately $14 million during the last year. The departmental educational programs are also strong. In the following sections, some of the important departmental activities of the past year are presented.

ACTIVITIES OF THE DEPARTMENT

On April 15, 1992, Professor William Orme-Johnson organized a Department-wide discussion on "Teaching in a Research University". It was a follow-up to the discussion held in October 1991 after the MIT colloquium. The agenda included: (1) What would make learning chemistry topics easier, surer, and more complete; (2) What programmatic goals, facility improvements, and service enhancements should we try to achieve in the future?

In the Fall of 1991, the Chemistry Department's Graduate alumni/ae telethon yielded a total of $11,950 from 104 donors plus 36 unspecified pledges which had been the best dollar per caller rate up to that point of the season. The volunteers, who represented a mix of alumni/ae and students, clearly understood the important role they played as goodwill ambassadors to the alumni/ae.

On January 13, 1992, the Chemistry Department held the First Annual MIT Graduate Research Symposium in Organic and Bioorganic Chemistry. The Symposium was comprised of five students' presentations, and was a great success.

The Department of Chemistry and the George R. Harrison Spectroscopy Laboratory sponsored the first annual Richard C. Lord Lecture on May 12th. Prof. Richard Lord was appointed Prof. of Chemistry in 1954 and was Director of the Spectroscopy Lab from 1946 to 1976. He died in 1989. Dr. Lord had a major impact on the development of the Spectroscopy Laboratory. Prof. Takeshi Oka, the first Lord Lecturer, is the Robert Millikan Distinguished Service Professor at the University of Chicago. The event was a great success, and the department intends to have an R. C. Lord Lecture in Spectroscopy every spring as a tribute to the memory of Dr. Lord.

IN MEMORIAM

We are saddened to say that **Professor Emeritus John C. Sheehan** passed away on Saturday, March 21st. Professor Sheehan's greatest accomplishment was achieving the first total synthesis of penicillin in 1959 after all other research groups had failed. Professor Sheehan had received many honors including election to the National Academy of Sciences, Honorary D. Sc. degree from the University of Notre Dame, Honorary D. Eng. from Stevens Institute of Technology and American Chemical Society's Award for Creative work in Organic Synthesis. He served as a consultant to the President's Scientific Advisory Committee, and he was a member of the Board of Directors of the American Chemical Society. He is survived by his wife of more than fifty years, three children and six grandchildren. The Chemistry Department will sorely miss this man who contributed so much to MIT.

PERSONNEL

At the meeting of the International Union of Pure and Applied Chemistry in Hamburg, Germany, August 6-15, **Professor Robert A. Alberty**, Professor of Chemistry, Emeritus, was elected President of the Physical Chemistry Division for 1991-1993.

Professor Moungi Bawendi was one of 20 recipients nationwide of 1991 Packard fellowships, which represent the nation's largest program of unrestricted grants to young university faculty members in science and engineering. The foundation said Professor Bawendi has earned an international reputation for his work in synthesizing semi-conductor particles and developing tools to understand their electronic states and properties.

At the 12th International Mass Spectrometry Conference held in Amsterdam, the Netherlands, August 26-30, 1991, **Professor Klaus Biemann** was awarded the J. J. Thomson Medal.

Ms. Melinda Cerny of our Undergraduate Office received the James Murphy Award at the Awards Convocation on May 6th. This award is given to an employee whose spirit and loyalty exemplifies inspired and dedicated service, especially with regard to students.

Four undergraduate members of the Department were recipients of National Science Foundation Fellowships for September 1992: Amy Bowen, C. David Sherrill, Adam Wagman, and Eric Zylstra. Hongbin Dai, C. David Sherrill, and M. Barbara Srichai were inducted into Phi Beta Kappa.

DISTINGUISHED VISITORS

The Chemistry Department was privileged to host six distinguished scientists in endowed lectureships during the past academic year. Professor Christopher Walsh, Harvard Medical School, was the T. Y. Shen Visiting Professor in September, 1991. Professor Paul Bartlett, University of CA, Berkeley, was the Procter & Gamble Lecturer in October 1991. Professor Richard Smalley, Rice University was an A. D. Little Lecturer in Physical Chemistry in March 1992. Professor Clayton Heathcock, University of CA, Berkeley was the George Büchi Visiting Lecturer in Organic Chemistry in March 92. Professor F. A. Cotton, Texas A&M University, was the A. D. Little Lecturer in Inorganic Chemistry in March 1992. Professor Robert Bergman, University of CA, Berkeley was the Karl Pfister Visiting Lecturer in Organic Chemistry in April 1992.

ROBERT J. SILBEY

Professor Sylvia Ceyer, whose internationally recognized research in surface chemistry has important applications in the conversion of natural gas to useable fuels, was named the first holder of the W.M. Keck Foundation Professorship in the field of energy. Professor Ceyer also was elected as a fellow of the American Academy of Arts and Sciences at its 212th annual meeting on April 8th.

Professor Alan Davison was presented with the 1992 Colgate-Palmolive Company Grant. Funding is presented to a member of the MIT Faculty each year.

Professor Daniel Kemp was one of six faculty members at MIT to be named a MacVicar Faculty Fellow. The MacVicar Faculty Fellows is a new program named for the late Margaret L. A. MacVicar in order to recognize faculty's exemplary and sustained contributions to undergraduate education.

Professor Alexander Klibanov was elected a Fellow of the American Institute for Medical and Biological Engineering. This honor is reserved for the top 2% of researchers working in this field. Professor Klibanov also was the winner of the 1991 International Enzyme Engineering Prize. Prof. Klibanov, who is the first American to have received this honor, was cited for his "pioneering work on enzyme catalysis in organic solvents and mechanisms of enzyme inactivation".

Professors JoAnne Stubbe and Richard Schrock were elected to the National Academy of Arts and Sciences.

Professor Scott C. Virgil joined the Chemistry Department in January 1992 as an assistant professor. Prof. Virgil received his PhD at Harvard and was a graduate student under Professor E. J. Corey. Prof. Virgil was awarded a Camille and Henry Dreyfus New Faculty Award for 1991.

Institute Professor John Waugh won the Theodore Williams Richards Medal for 1992. The medal is awarded every two years by the Northeastern Section of the American Chemical Society "for conspicuous achievement in Chemistry".

GRADUATE STUDENTS

During the 1991/92 Academic Year, the Department admitted 48 students into the Ph. D. Program and awarded 44 Ph.D. degrees and 4 S.M. degrees. Although the graduate student population remains constant at approximately 250, there was a significant increase in the number of graduate students on fellowships and traineeships: Graduate students on fellowships increased 53% with 55 fellows, compared to 36 during the previous year. Graduate students on traineeships totaled 25, compared to 23 for the same period last year, for an increase of 8.6% . There were 22 new fellowships during the year: The ACS Fellowship was awarded to Karen R. Romines of the Danheiser group, the Arthur D. Little Fellowship to Ernest (Foss) Hill of the Field group, the Bristol-Myers Squibb Fellowship to Christopher Willoughby of the Buchwald group, the Clare Boothe Luce Fellowship to Katherine Liu of the Lippard group, the Department Fellowship to Bashir Dabbousi of the Bawendi group, the D.O.D. Navy Fellowship to Katherine Lee of the Danheiser group, the F.A.C.R. Fellowship to Simon Delagrave of the Youvan group and Gino Lavoie of the Schrock group, the Greenlaw Fellowship to Julie K. Thomas of the zur Loye group, the Howard Hughes Medical Institute Fellowship to Patrick Zarrinkar of the Williamson group, the Milas Fellowship to Ted Ashburn of the Lansbury group, the Moore Outreach to Benjamin Warner also of the Lansbury group, the N.S.F. Fellowship to James J. Claus of the Guarente group, David E. Coufal of the Orme-Johnson group, Maria F. Tymoschenko of the Rebek group, Edward A. Wintner also of the Rebek group, and Scott Blackwell of the Schrock group, the N.S.E.R.C. Fellowship to Marc M. Wefers of the Nelson group, the Paul Cook Fellowship to Manoj Nirmal of the Bawendi group, the Proctor & Gamble/France to Christophe Pellet, the Syntex Fellowship to Jeffrey Rothman of the Kemp group, and the Technology and Policy Fellowship to Eugene Bae of the Deutch group.

Activities in placement assistance to postdocs and graduating Ph.D. candidates, which have included over the past 2 years information sessions on résumé writing, interview preparation, and how to choose between offers, have been expanded to include a session on preparation for the first 3 months on the job. Despite the economy, the number of companies that interviewed in the Department during Fall 1991 totaled 49, down from the 54 that visited the Department the previous year. Several graduate students received awards this past year. Anna Helgason received the Ayukawa Prize and Paul Burke received the Ayukawa Travel Prize. Jackie Acho, Jennifer Caulfield, Michelle Milne, Marshall Morningstar, Jon O'Brien and Jerry Tkacz were the proud recipients of the Graduate student TA Awards presented for the first year in the Chemistry Department.Their commitment to excellence in teaching was extraordinary. Jackie Acho also won the Goodwin Medal. Theresa Kavanaugh received an NSF Postdoctoral Fellowship.

UNDERGRADUATE STUDENTS

The Department awarded several chemistry undergraduates with the following awards: Robert T. Li, Cynthia A. Parrish, and C. David Sherrill received Alpha Chi Sigma Awards for achievement in research, scholarship and service to the department. Hongbin Dai and M. Barbara Srichai received the Merck Index Awards for outstanding scholarship; and Amy Bowen, Eric Dias, and Geoffrey Kuziemko received the Undergraduate Research Awards for outstanding contributions in Chemistry research by an undergraduate.

Department of Earth, Atmospheric, and Planetary Sciences

INTRODUCTION

The Department of Earth, Atmospheric and Planetary Sciences (EAPS) is one of the broadest and best integrated earth-science organizations in the world. Its research mission is to investigate the workings of the Earth's interior, oceans and atmosphere, as well as the other planets of the solar system, and to understand the dynamical relationships that govern weather, climate, and the Earth's long-term geological evolution. Its educational mission is to train the best students for careers in earth-science research and to encourage them to attack some of the most fundamental problems confronting a globalized society. These problems range from the search for new natural resources to the effects of greenhouse-gas emissions on the global climate.

EAPS comprises 38 faculty, 77 research staff, 30 support staff, and 172 graduate students. All of the faculty are engaged in both research and teaching. Nearly all of the graduate students (94 percent) are working towards a Ph.D. degree. Although the interdisciplinary nature of the EAPS activities make divisions by field somewhat arbitrary, the research and teaching is organized in terms of five disciplinary groups: Geology and Geochemistry, Geophysics, Planetary Science, Oceanography, and Atmospheric Science.

Several organizational structures overlay these disciplinary groupings. The department administers the Earth Resources Laboratory (ERL), the Center for Meteorology and Physical Oceanography (CMPO), and the Center for Global Change Science (CGCS). In addition, it is a major participant in the Center for Space Research (CSR) and the Joint Program in Oceanography and Oceanographic Engineering between MIT and the Woods Hole Oceanographic Institution (WHOI).

FACULTY AND RESEARCH STAFF

Changes in the EAPS faculty included the appointment of Dr. John C. Marshall as an untenured Associate Professor. Professor Marshall is a oceanographer/meteorologist and is known for his work in modelling the large-scale oceanic circulation and in analyzing both theory and observations of the persistent structures in the atmosphere. His specific contributions have been mainly in the area of the interaction between turbulent elements of the atmosphere and ocean and their interaction with the larger scale flows.

Professors Raphael Bras and Peter Eagleson of the Department of Civil Engineering were given joint (secondary) appointments in EAPS in recognition of their continuing contributions in EAPS's expanding programs in hydroclimatology and global change science. Dr. Randall Dole, an untenured Associate Professor of meteorology, left the department for a permanent position at Cooperative Institute for Research in Environmental Sciences in Boulder, Colorado.

On July 1, 1992, Paola Malanotte-Rizzoli was promoted to Professor, and John Grotzinger and Thomas Herring were promoted to Associate Professor with tenure.

Honors

Professor John Southard was appointed one of six inaugural MacVicar Faculty Fellows for a ten-year tenure in recognition of excellence and innovation in undergraduate education at MIT. Professor John Grotzinger was awarded the Donath Medal at the Geological Society of America. Professor Richard Binzel received the 1991 Harold C. Urey Prize by the Division for Planetary Science of the American Astronomical Society. Professor Kerry Emanuel was honored by the Banner Miller Award of the American Meteorological Society. Professor Gordon Pettengill received the National Space Club Science Award and the NASA Exceptional Scientific Achievement Medal for accomplishments in the Magellan Mission. Professor Jack Wisdom was elected to the American Academy of Arts and Sciences, and Professor Carl Wunsch was elected a Fellow of the American Meteorological Society. Professor Marcia McNutt has been appointed to the Griswold chair. Professor Ed Boyle received a Guggenheim Foundation fellowship for his sabbatical research at the Centre des Faibles Radioactivites (CNRS) laboratory in Gif-sur-Yvette, France.

EDUCATION

Curriculum revision continues to be a high priority on both the undergraduate and graduate levels. The revised undergraduate degree program is in its second year of implementation; each of the new core subjects has garnered increased enrollments and favorable student evaluations. The collaboration between EAPS and Civil Engineering through the Center for Global Change Science will result in new subjects being offered jointly by both departments in the 1993 academic year: 12.302J Water in the Global Environment and 12.320J Introduction to Hydrology (both undergraduate-level subjects), and 12.825J Sampling, Synthesis, and Forecasting of Hydrologic Processes and 12.826J Landsurface-Atmosphere Interaction (graduate-level subjects).

As part of a School of Science initiative, the EAPS faculty this year approved a new program which will allow undergraduates to minor in Geoscience or Planetary Science. The proposed Minor Program is expected to be approved by the Institute for implementation in the 1994 academic year.

CENTER FOR GLOBAL CHANGE SCIENCE

The Center for Global Change Science (CGCS) was established in 1989 to address scientific problems related to large-scale, long-term environmental changes. The interdisciplinary center involves both research and education, and builds on established programs in meteorology, oceanography, hydrology, and satellite remote sensing carried out in the Schools of Science and Engineering at MIT. CGCS is directed by Professor Ronald G. Prinn of EAPS; its Associate Director is Professor Rafael L. Bras of the Department of Civil Engineering. The goal of the center is to sustain a program of basic scientific research focused on the fundamental processes in the global climate machine, with the specific objective of improving the prediction of anthropogenic environmental changes. CGCS coordinates its activities with other relevant groups at MIT with the help of the new MIT Council on the Global Environment.

CGCS has pursued several major objectives over the past year. One of these, the Joint Program on the Science and Policy of Global Change, has hosted two very successful Global Change Forums in which high-level participants from government, industry, and academia engage in significant discussion and debate on scientific and societal issues regarding the possibility of global climate change. The joint program, a collaboration between CGCS and the Center for Energy and Environmental Policy Research, has received significant industry support and is now proceeding into its first research phase involving integrated climate and economic modelling. The climate modelling in this program, the ongoing search for a new EAPS faculty member in atmospheric modelling, and a major planned MIT meeting of climate modellers this fall all contribute to the ongoing efforts to improve and expand the climate modelling capability here at MIT. The center ran a very successful international symposium this year entitled "The World at Risk: Natural Hazards and Climate Change". A book will be published shortly devoted to the proceedings. The location of the International Global Atmospheric Chemistry (IGAC) Core Project Office within the CGCS during the past year gives the center international prominence in atmospheric chemistry issues associated with global change.

CURRENT RESEARCH

Atmospheric Science

The atmosphere in the trade wind zone of the western Pacific has a fetch on the order of 10,000 km and the air is expected to be relatively unpolluted. By contrast, air originating over the East Asian continent can pick up the products of industrial pollution and biomass burning whenever convection is present and move them over the ocean. The interaction between these two air masses was studied experimentally in September and October 1991 using the NASA DC-8 aircraft to measure over 40 atmospheric constituents and the standard meteorological variables like wind velocity, relative humidity and temperature. Professor Reginald E. Newell chaired the group that planned the Pacific experiments, flew over 100 hours on the DC-8 flight deck and was responsible for weather forecasts for each mission including the penetration of super-typhoon Mireille. The typhoons encountered appear to pick up biospheric gases from the sea surface and rapidly carry them to heights of 12 km. Professor Newell and his group, W. Hu, Z-X. Wu, and Y. Zhu, are now working on the atmospheric and chemical interpretation of the results.

Professor Prinn and coworkers have obtained the first definitive evidence from atmospheric observations that industrial emissions of the two major chlorofluorocarbons ($CFCl_3$, CF_2Cl_2) are finally decreasing in response to regulations. Using global measurements of these trace gases in the Global Atmospheric Gases Experiment, they deduce that annual industrial emissions of $CFCl_3$ and CF_2Cl_2 decreased from historical high values in 1988 of 344 and 520 billion grams respectively, to much lower values of 264 and 379 billion grams respectively in 1990. Hydrochlorofluorocarbons, which are generally much shorter-lived and decompose mainly in the lower atmosphere, are now replacing these chlorofluorocarbons in many uses.

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 elucidated the mechanism and measured the rates of these cloud-induced reactions that release active chlorine in the stratosphere. Furthermore, they have successfully developed a flow technique to study gas phase chemical reactions at temperatures as low as those prevailing in the polar stratosphere.

Professor Earle Williams is using the Schumann resonance (SR), a global electromagnetic phenomenon driven by lightning activity, as a sensitive diagnostic for surface temperature variations in the tropical atmosphere. The observed doubling of the SR amplitude for a 1°C temperature perturbation for the entire tropical belt is consistent with local measurements of the sensitivity of lightning activity to changes in surface wet bulb temperature. On the El Niño time scale (~40 months), the temperature and lightning activity of the three major zones of deep tropical convection are all in phase. These observations over long time scales strongly suggest that global lightning will increase in a warmer climate.

Professor Kerry Emanuel conducted a major field program, the Tropical Experiment in Mexico (TEXMEX), which he had organized and planned during the previous two years. TEXMEX was designed to test several theoretical hypotheses about the origin of tropical cyclones. Preliminary analysis of this data set reveals a remarkable sequence of events leading up to fully developed hurricanes. He has spent a one semester leave-of-absence implementing his own representation of cumulus convection in the weather forecast model of Meteo France and finishing a graduate-level text on atmospheric convection.

Professor Peter Stone and Dr. Jochem Marotzke have initiated a project to develop an improved understanding of how the atmosphere and the oceans interact on climate time scales. The project will involve the construction of a series of increasingly sophisticated coupled atmosphere-ocean models. During the past year, the first model, a simple five-box model describing the interaction of the ocean's thermohaline circulation with the atmosphere's hydrological cycle, was developed and studied. The results revealed a previously unidentified positive feedback mechanism between the latitudinal temperature gradient and the poleward heat transport by the thermohaline circulation.

Professor Richard Lindzen has been continuing his work on the general circulation, weather prediction, planetary atmospheres, and climate dynamics. He and his collaborators have explained why satellite temperature data tend to degrade weather forecasts, have shown how consideration of meridional heat fluxes explains the 100 thousand year cycle in glaciation, have discovered a new neutral state for the atmosphere which offers some insights into the nature of the midlatitude tropopause, have been able to use both paleoclimatic data and climatic responses to volcanoes to estimate current climate sensitivity, have shown how initialization procedures for weather forecasting can degrade forecasts of planetary scale waves, and have formulated the theory of gravitational tides on the outer planets. The latter shows how allowing very small convective stability in the planetary interior allows one to account for the tidal dissipation required by the satellite orbits.

Professor Alan Plumb and his students are currently investigating the full three-dimensional structure of the springtime breakdown of the Antarctic polar vortex and the concomitant transport of ozone-depleted air into midlatitudes of the southern hemisphere. During winter 1991-2, Professor Plumb participated in NASA's Second Airborne Arctic Stratosphere Experiment, operating from Bangor, Maine, which is investigating the dynamics and chemistry of the Arctic stratosphere, including ozone depletion. Plumb's group is also using a contour dynamics model to elucidate the dynamics of the polar vortex and its interaction with breaking, large-scale waves and to study the dynamical behavior of synoptic eddies in the troposphere. They are also collaborating with NOAA's Geophysical Fluid Dynamics Laboratory at Princeton in investigations of climate and its variability in general circulation models.

Professor Rafael Bras has been concentrating on developing understanding of the interaction of land surface hydrologic processes and atmospheric phenomena. The studies have led to (a) a characterization of soil moisture climate as a highly nonlinear, chaotic process; (b) the description of river basin development and structure as a function of climate, geologic setting, and soil properties; and (c) quantification of the level of moisture recycling in the Amazon.

Professor Peter Eagleson has continued his efforts to define the biophysical constraints determining the geographical boundaries of major vegetation types. Study of several natural pinyon-juniper watersheds near Flagstaff, Arizona, where data were available on biomass productivity and on soil hydraulic properties as well as on climate, strongly supports the hypothesis that the vegetation canopy cover takes on the largest value consistent with minimum average water-demand stress. This work may provide an estimator for soil properties in semi-arid climates and should contribute to the parameterization of land surface boundary conditions in atmospheric general circulation models.

Oceanography

Professor Boyle and his paleoceanography group have completed a global map of deep ocean nutrient distributions during the most recent ice age using the proxy analogue cadmium. They have also researched the use of fluoride as a paleoceanographic tracer and proven it to be more problematic than others had suggested. Professor Boyle's chemical oceanography group has demonstrated that oceanic particles rapidly equilibrate with dissolved anthropogenic lead. They are also devising an in-situ moored instrument for the collection of uncontaminated time-series seawater samples.

The highlight of the year for Professor John Edmond was a five-week expedition to the headwaters of the Lena River in the Russian Far East. Detailed sampling was made of 32 tributaries for the chemistry of the dissolved and suspended load and the bed sands. Over 3,500 kilometers were traversed on a great variety of river craft. The expedition ended in Moscow in time for the "coup"! An expedition to the Kolyma is planned for the 1992 season. This spring has also seen an active exchange program with four Russian scientists visiting MIT and other United States institutions as part of the project. Edmond's group was also involved in two ALVIN dive series, on the Endeavour Ridge in the Northeast Pacific and at 21°N on the East Pacific Rise.

Professor Marshall and his coworkers are attempting to understand and model key components of the general circulation of the atmosphere and oceans. During the past year his research has focused on the structure of the main thermocline of

subtropical ocean gyres and those factors that control the rate at which they are ventilated from surface mixed layers. Another major research thrust has been to advance the understanding of deep-reaching convection in the ocean, the sinking branch of the thermohaline circulation. Powerful (and useful) scaling laws have been advanced and supported by numerical study; they address the dominant space, velocity and buoyancy scale of open-ocean convective plumes and the geostrophically adjusted end-state of that convective process. The research is suggesting new ways of parameterizing convection in the large-scale models used for climate research.

Professor Glenn R. Flierl and his students are investigating the evolution of strong eddies and jets in oceans and atmospheres. He and Dr. Stephen Meacham (Florida State University) have calculated the shapes and propagation speeds for nonlinear Gulf Stream meanders using simple models. These are being extended to include other important aspects of the dynamics such as the large excursion of the thermocline compared to its mean depth. They are comparing the results with both the data from the observational part of the SYNOP program and other, more conventional, models. With Cabell Davis (WHOI), they have demonstrated that the meander-induced vertical velocities can significantly alter the biological distributions. An extensive study of the interaction of a Gulf Stream ring with the continental shelf has demonstrated that the eddy pulls off shelf water which spins up into a small but strong vortex. This then pushes the eddy away from the shelf, but in a curved path, so that it will again strike shelf further to the west. In addition, shelf waves are generated during each of these interactions. Finally, he and collaborators are examining the influence of vertical and horizontal shear, of the radiation of planetary waves, and of deep flows on strong eddies such as Jupiter's Red Spot.

Professor Paola Malanotte Rizzoli and her group have continued in their research efforts mainly focused on two regions, the extended Gulf Stream System that reaches into the Northeastern Atlantic and the Mediterranean Sea. Studies related to the Gulf Stream System have concentrated on assimilation of GEOSAT data into a regional numerical model, assimilation of data sets from the localized clusters collected during the SYNOP experiment, and process studies of the wave radiation field associated with the Stream and of wave/mean flow interactions. The Mediterranean research has focused on assimilation of hydrographic data into a model of the Mediterranean general circulation, and process studies of water mass formation, dispersion and mixing.

Professor Carl Wunsch and his collaborators have continued to explore the ocean circulation and its role in climate through the combination of dynamical models and observed data. The World Ocean Circulation Experiment is now underway, and producing a growing data stream. The crucial altimetric spacecraft, Topex/Poseidon, should be launched in August 1992, and will provide the major observations for determination of the circulation and its variability. Efforts to produce global scale models for combining these and other data for estimates of the circulation continue.

Dr. Jochem Marotzke is collaborating with Professor Carl Wunsch in an investigation of whether a steady-state circulation of the North Atlantic ocean can be found which is consistent both with the dynamics of a general circulation model and observations of temperature and salinity. The results suggest that the concept of a strictly steady state compatible with data must be abandoned and that an appropriate climatology must resolve the seasonal cycle. He and Professor Andrew J. Weaver of McGill University, Montreal, have investigated the stability and variability of the thermohaline circulation using a general circulation model in idealized configurations. They find that the surface flux of freshwater is the dominating factor in determining the model's behavior; i.e., moderate changes in the freshwater forcing cause dramatically different model responses.

Geology and Geochemistry

Hotspots in the earth's mantle form ascending plumes that are interpreted to be the cause of massive episodes of terrestrial volcanism, e.g., the Deccan Plateau which formed in India at the Cretaceous-Tertiary boundary. Subsequent to this brief period of intense volcanism, only about one million years in duration, linear volcanic traces form on the plate moving over the mantle plume. Two spectacular hotspot traces are in the Indian Ocean: (1) Deccan Plateau, Chagos-Lacadive Ridge, Reunion Island; and (2) Rajmahal volcanics, Ninetyeast Ridge, Kerguelen Archipelago. Two legs of the Ocean Drilling Program focussed on drilling and recovering seafloor samples along these hotspot traces. Professor Frederick Frey and colleagues who participated in these oceanographic expeditions have found that the ages of these seafloor samples are consistent with the Indian Ocean plate moving over stationary hotspots, but that the temporal geochemical variations require that the plume compositions and extents of partial melting within the plume have varied with time.

Professor Tim Grove and his colleagues have initiated an experimental program that will provide a framework for understanding the processes and physical conditions that led to the formation of the metallic cores of the terrestrial planets. The experiments investigate the influence of variable oxidation state on the partitioning of siderophile (metal-loving) elements among silicate melt, silicate minerals and iron metal. The silicate minerals left behind after the core-formation event provide a chemical signature of the process, and the experiments allow interpretation of the siderophile element abundances preserved in these silicate residues. The experiments have revealed a previously unrecognized effect of variable oxidation state on siderophile element partitioning. Variable oxidation state changes the valence of a siderophile element in the silicate melt, thereby controlling the extent to which that element is incorporated into the lattice of the silicate mineral.

The results have been used to estimate the extent of melting and the amount of residual metal present in the moon and the parent body of the eucrite meteorites. These planetesimals are ideal for initial tests of the method because the samples from them are ancient (~4 billion years old), the melting process was short lived, and the melting process ended soon after the core-formation event. This work is currently being expanded to elucidate the conditions under which the earth's core segregated from the upper mantle.

Professor Roger Burns and colleague investigators are studying rates of chemical weathering reactions that might be applicable to the surfaces of Venus and Mars. Kinetic studies in hot CO_2 atmospheres showed that the conversion of hematite to magnetite is sufficiently rapid at vesuvian surface temperatures so as to dismiss the existence of hematite on Venus. Deposition of ferric-bearing oxides and clay silicates, which are produced by rapid acid weathering of basaltic rocks, from periodic oceans in the northern hemisphere of Mars may have regulated oxygen in the Martian atmosphere when water flowed on the Red Planet. Similar processes probably occurred on Earth during the Archean era.

Professor Samuel Bowring and his research group are focussed on understanding the growth and development of continental crust and lithospheric mantle. The tools used by this group involve geologic mapping coupled with geochronologic, isotopic, and geochemical studies. Bowring is working on a variety of problems in North America. He has been documenting the age, geochemistry, and isotopic composition of the oldest rocks known, the 4.0-billion-year (Ga) Acasta gneisses and has shown that these rocks were derived from a LREE-depleted mantle, indicating the mantle must have been strongly depleted by ca. 4.0 Ga. In addition, the isotopic studies have shown that these rocks preserve a large degree of isotopic heterogeneity, providing clues to the early differentiation of the Earth and an important comparison for the early history of the moon.

Bowring is also working on the growth of the southern part of the North American continent between 1.8 and 1.0 Ga. A central theme of this work is to establish lithospheric boundaries in this broad (100-km) orogenic belt that can be used to correlate with other continents that may have been part of North America 1.0 Ga. One of exciting conclusions of this research is that the orogenic belt preserves lithospheric-scale heterogeneities that have been repeatedly re-activated through time. In addition, Bowring and his students have shown that in many cases, large parts of the orogenic belt were uplifted up to 200 Ma after assembly giving rise to U-Pb and K-Ar ages that indicate very slow cooling at mid-crustal levels.

Professor John Grotzinger continues to work on the documentation of late Archean (3.0 - 2.5 Ga) calcium carbonate sediments in an effort to determine the saturation state of seawater at that time and the partitioning of carbon between the crust, ocean and atmosphere. A new project has been started on evaluating what earth surface processes were coincident with the origin of metazoan life at the end of Proterozoic time (ca. 600 Ma), and to what extent these processes occurred on a global scale. This work is being done in collaboration with Russian and Namibian geologists.

Professor Kip Hodges and his students are concentrating their efforts on a better understanding of the relationships between thermal and tectonic processes at deep structural levels in orogenic belts. Research in the western United States has provided exciting new evidence that gravitational collapse of the Sevier orogenic belt may have played an important role in the Late Cretaceous-Paleocene magmatic evolution of the North American Cordillera. Research in Nepal and southern Tibet continues to enhance an appreciation of the complexities of the Himalayan orogen. During recent field work near the Annapurna massif in central Nepal, Hodges and Dr. R. R. Parrish of the Canadian Geological Survey discovered a major thrust fault of probable Miocene age that may have a tectonic significance as great as better known structures such as the Main Central Thrust. An important aspect of the current research of Professor Hodges and students is the use of the newly established Ar geochronology facility at MIT to examine the time-temperature history of metamorphic terrains and to obtain high-precision ages for young volcanic rocks. Most recently, research in this laboratory has bracketed the age of Tertiary extensional faulting in the Bitterroot Mountains of Montana to within two million years.

Professor Leigh Royden was on sabbatical for the 1991-1992 academic year, which she spent at Caltech as part of NSF's Visiting Professorships for Women Program. While on sabbatical she continued her studies on continental deformation in China and Tibet by analyzing the relationship between crustal deformation and mantle motions in zones of continental convergence using a thin-sheet approximation for crustal flow. This work has revealed that there is a simple relationship between basic crustal flow patterns relative to the mantle and topographic elevation, and thus offering the possibility of determining mantle motions beneath Tibet and other regions of young compressive deformation.

Professor Clark Burchfiel spent his sabbatical year continuing field studies in several areas of China to understand the development of the Tibetan Plateau, the mountain ranges north of the Plateau, and the eastern part of China extending to the South China Sea. The last year's work, done in cooperation with the Chengdu Institute of Geology and Mineral Resources, Sichuan, have focused on the geology of the Long Men Shan and mountains of Yunnan that form the eastern margin of the Tibetan Plateau. Studies to date suggest that eastward movement of continental fragments within the plateau are being absorbed in shortening along the eastern margin of the plateau. The field work is part of larger cooperative effort that integrates geological, geodetic and geophysical studies. Burchfiel and Dr. Robert King have established a geodetic network

of 11 Global Positioning System (GPS) stations in the region of the Long Men Shan to provide precise data on active motions in this part of Sichuan; another network will be established this year in Yunnan to determine the modern strain along the eastern margin of the plateau. Geophysical studies done in collaboration with Professor Royden are being focused on understanding the evolution of the thick eastern Tibetan crust, its relation to the India-Eurasia collision, and the effects of the plateau on the lithosphere of the South China Sea.

In cooperation with colleagues at Johns Hopkins, the University of Minnesota, and the University of Tsukuba in Japan, Professor John Southard is engaged in two large-scale experimental projects to address one of the central problems in physical sedimentology—how the texture of a particulate sediment depends upon the conditions of transport and deposition. So far, three time-consuming runs in which forty tons of coarse sediment are put through their paces by an army of professors and students have shown that the degree of downstream fining by hydraulic fractionation in aggrading rivers is inversely related to the strength of the sediment-moving flow. Further runs, using even more sediment, will be aimed at studying the possible effects of lateral fractionation in wider channels.

Geophysics

Professor Thomas Herring has been investigating the applications of high precision space-based geodetic systems. He recently demonstrated that very long baseline interferometry (VLBI) was capable of making sub-millimeter precision measurements over nearly a decade. He also established that the Earth has diurnal and semidiurnal variations in its rotation rate and in the position of its rotation axis which are largely driven by tidal ocean currents. In the future, these types of studies are likely to be carried out using the Global Positioning System (GPS), and Professor Herring and his students and coworkers were the first to show, by direct comparison of VLBI and GPS, that GPS measurements were capable of determining daily pole positions with sub-milliarcsecond accuracy. In other applications of GPS, Professor Herring in conjunction with Professor Hager, Dr. Robert King and graduate students have been combining GPS and VLBI measurements to form a large-scale map of the velocity field in California. Professor Herring has also collaborated with personnel at the Jet Propulsion Laboratory (JPL) in a comparison at atmospheric propagation delays determined from collocated GPS and VLBI systems.

Professor Bradford Hager and his colleagues are conducting numerical experiments investigating thermo-chemical convection in the mantles of the terrestrial planets. Graduate student Steve Shapiro, Hager, and Professor Thomas Jordan have found that the combination of temperature-dependent viscosity and compositional buoyancy can explain the stability of the subcontinental lithosphere (tectosphere). Graduate student Jim Gaherty is investigating the fate of subducted lithosphere in calculations that include the compositional buoyancy of the subducted crust and depleted lithosphere. Graduate student Mark Simons, Hager, and Professor Sean Solomon are investigating the interaction of mantle convection and crustal deformation on Venus, constraining their models with the new observations from the Magellan spacecraft.

Hager and Principal Research Scientist Robert King are continuing their space geodetic measurements of crustal deformation in the Ventura basin region, southern California. Using repeat GPS measurements, they find that the strain building up there is larger than that associated with the San Andreas fault, a result with important implications for evaluating seismic hazard. Principal Research Scientist Rob Reilinger, Senior Research Scientist Peter Molnar, and Hager are also initiating GPS measurements in the Tien Shan Mountains of central Asia. Hager, King, and visiting scientist Peter Morgan of the University of Canberra are developing a program to use space geodesy to monitor global change; changes in ice sheet mass extensive enough to cause observable changes in global sea level also cause elastic displacements of the solid Earth large enough to be measured using space geodesy. EAPS sent one of its GPS receivers to Antarctica this past austral summer to be part of a geodetic network that has as one of its applications "weighing" changes in ice sheet mass.

Dr. Robert Reilinger has been using conventional and space geodetic observations to study present day deformation of the Earth's crust—plate motions, earthquake and volcanic processes—in a number of tectonically active areas including the Eastern Mediterranean (with Professor M. Nafi Toksöz), Southern California-Northern Mexico (with Dr. Robert King), the Northern Rocky Mountains, and Soviet Central Asia. Dr. Reilinger directed a rapid, post-earthquake GPS survey following the March 1992, M=6.9 Erzincan, Turkey earthquake, the first post-earthquake GPS response for an event outside the United States. Observed deformations are being used to constrain the nature of faulting associated with this earthquake.

Professor Ted Madden and post-doctoral associate Randy Mackie have collected telluric and magnetotelluric data on sections of the San Andreas fault zone, and this data may shed some new insights about the role of the lower crustal part of the fault zone. The Loma Prieta lower crust shows a dramatic increase in the conductivity of this zone compared to normal lower crustal zones, and, given the time scale since the earthquake activity, it must be assumed that an unusual amount of water was present in the zone before the earthquake. If the fluids were poorly connected before the earthquake, high fluid pressures would be expected which could play a role in the mechanics of the fault system. This raises questions about the time variations of the electrical conductivity of the lower crust that were observed for a number of years in a section of the locked part of the San Andreas near Palmdale, California.

Dr. Peter Molnar and Mississippi geologist John Kaye have determined that the Tennessee River flowed directly from the southern Appalachians to the Gulf of Mexico until Pliocene time. This interpretation is based in part on Kaye's mapping of distinctive metamorphic cobbles, whose origin is surely the southern Appalachians, but which are now distributed over much of the area south and west of the Tennessee River watershed. Flexure of the North American lithosphere during the Illinoian or earlier glacial advance probably caused this recent course change. Moreover, a stormy climate during the cold Plio-Pleistocene times may have accelerated erosion. This change shows that major changes in the landscape can occur in response to climate change in regions where tectonic activity is low.

Professor Marcia McNutt conducted the first complete survey of a major Pacific fracture zone. Using multibeam sonar imaging and gravity, magnetic, and seismic profiling, she and colleagues mapped the Marquesas Fracture Zone for more than 3000 km. Their discovery of the western termination of this fault pinpoints the previously undetermined locus of the major Cretaceous plate reorganization which established the Pacific-Farallon system of ridges and transforms. Their detailed cross-sections of the fault will be used to constrain thermo-mechanical models of interaction of the French Polynesian hot spots with faults and of aging of oceanic lithosphere across large thermal discontinuities. The expedition was staffed by undergraduate majors in Physics from Eckerd College for the purposes of exposing students at small, liberal-arts colleges to research and of introducing them to the excitement of Earth sciences.

Professor Daniel Rothman and his students have created, studied, and applied new models of complex geophysical fluids in two and three dimensions. The models are based upon discrete lattice-gas hydrodynamics, and allow simulation of non-Newtonian fluids, suspensions, and various multiphase flows. One objective of this work is to determine the constitutive equations and aggregate properties of complex flows of complex fluids. A recent result has shown the limitations of the Darcy's law for multiphase flow through three-dimensional porous media, in addition to showing how multiple fluids are viscously coupled.

To measure the effect of petrographic composition on the strength of rocks in the transition between plastic flow and brittle failure, Professor Brian Evans and colleagues have developed techniques to fabricate synthetic rocks of controlled composition and microstructure. Matrix grain size, second phase content and grain size, and porosity may be systematically varied. The results of the experiments have been compared with tests on natural rocks and suggest that even relatively small variations in porosity and second phase content can have sizable effects on the strength of the rock.

Professor Sean Solomon and his students have been actively analyzing the radar images and altimetry of the surface of Venus returned by the NASA Magellan mission. They are focusing on the tectonics of Venus, particularly on the nature of mountain belts, rift systems, and other major deformational features and on the implications of the scales and patterns of deformation for the dynamic and mechanical structure of the planet's interior.

Professor M. Nafi Toksöz, in collaboration with research scientists Drs. Richard Coates and Anton Dainty, has been working on characterizing by seismic means the small-scale heterogeneities in the crust. They have been analyzing the amplitude and phase variations of seismic waves recorded by arrays of well-calibrated seismic instruments. The largest array has a diameter of 100 km (NORSAR), and the smallest 300 meters (Piñon Flat). The results so far show that the heterogeneities are most pronounced at the upper crust and they decrease gradually with depth. Spatial variation is best matched by a self-similar or zero-order von Karman distribution.

Dr. Arthur Cheng, together with graduate student Ningya Cheng, developed a method of estimating shear-wave anisotropy from borehole acoustic logging data. This technique can be applied to estimate fracture direction and the magnitude and direction of the in-situ stress in the crust. Dr. Cheng also developed a new expression for estimating the amount of fractures from shear-wave anisotropy.

Professor Thomas Jordan and graduate student Peter Puster have developed a new approach to extracting information about earth structure from seismographic recordings of the earth's low-frequency free oscillations, and they are applying the methodology to the study of aspherical heterogeneity in the mantle. Graduate student Jim Gaherty, collaborating with Jordan and Dr. Lind Gee of U.C. Berkeley, has obtained a new seismological model for the upper mantle beneath the older region of the Pacific Ocean that places interesting constraints on the nature of upper-mantle anisotropy. Jordan and graduate students Pierre Imhlé and Paolo Harrabaglia are continuing an investigation of anomalous low-frequency radiation from certain types of large earthquakes that may indicate the existence of short-term, slow strain release prior to the elastodynamic rupture. If substantiated, these results would have profound implications for short-term earthquake prediction.

Planetary Science

Professor Timothy Dowling and his group are building the first state-of-the-art atmospheric general circulation model for Jupiter, Saturn, Uranus, and Neptune. Called the EPIC (Explicit Planetary Isentropic-Coordinate) atmospheric model, it will make real-time weather predictions for Jupiter and Saturn that will impact the choreography of imaging sequences during multi-year orbiter missions like Galileo and Cassini. By combining the EPIC atmospheric model and its

predecessors with Voyager data, Dowling has established the means for in-depth investigations into the basic dynamical processes at work in objects such as Jupiter's Great Red Spot and Neptune's Great Dark Spot. During the last year, Dowling solved a long-standing problem concerning how Jupiter's multiple jet streams are able to violate the Rayleigh-Kuo stability theorem by showing that Jupiter's winds are neutrally stable with respect to Arnol'd's second stability theorem.

Professor Jack Wisdom is continuing his studies of the long term evolution of the solar system. He and Professor Gerald Sussman have used a new special purpose computer to integrate the evolution of the whole solar system for 100 million years. The integration indicates that the whole solar system is chaotic with a time scale for exponential divergence of nearby trajectories of only five million years.

Professor Gordon H. Pettengill continues his involvement in the Magellan radar mapping mission to Venus, which has returned extremely high-resolution synthetic-aperture images of more than 96 percent of the planet's surface since reaching Venus in August, 1990. Using data from an ancillary radar altimeter on board the orbiter, he has supervised the preparation of global maps of the topography and surface electrical properties using facilities at the MIT Center for Space Research. Together with Professor Solomon, he is also involved in an experiment using a laser altimeter to be placed in orbit around Mars in 1993, with the aim of yielding a high-resolution map of the topography of that planet, as well as information on the presence of dust storms and surface fog.

Professor Richard P. Binzel and graduate student Noriyuki Namiki successfully predicted the <500 million year age and non-equilibrium crater distribution for 951 Gaspra, the first asteroid visited by a spacecraft. Their predictions were substantiated during the October, 1991, *Galileo* flyby. In separate work, groundbased observations and analyses by Binzel and coworkers also successfully predicted the size, shape, and spin vector for Gaspra.

Professor James Elliot, graduate student Leslie Young, and their colleagues have detected weak absorptions at 2.15 and 2.35 microns in the spectrum of Pluto with the United Kingdom Infrared Telescope at Mauna Kea Observatory, where Elliot spent his sabbatical year. They identify these latter two features as the 2.15 micron absorption of N_2 ice and the (2, 0) band of CO ice, respectively . Since N_2 has the highest vapor pressure of these gases, it would therefore be the dominant gas in Pluto's atmosphere, followed by CO and CH_4, supposing these gases are in vapor pressure equilibrium. Also, Elliot, graduate student Amanda Bosh, Dr. Maren Cooke, and their colleagues successfully observed a stellar occultation by Saturn's rings with the High-Speed Photometer aboard the Hubble Space Telescope. They are currently working with these data to establish a more reliable direction for Saturn's rotational pole and the scale of its ring system.

Dr. Heidi B. Hammel recently completed an analysis of near-infrared images of the planet Neptune, obtained as part of her long-term monitoring program at Mauna Kea Observatory in Hawaii. She found that Neptune had undergone an unusual atmospheric outburst in the years 1986-1988; the disturbance was confirmed by independent observations form Lowell Observatory in Flagstaff, Arizona. In addition, she and graduate student Leslie Young studied Neptune's infrared spectrum from 7 to 14 microns; they found that ethane emission in the planet's stratosphere had increased significantly during the past decade. She is also is continuing her analysis of simultaneous ground-based and spacecraft imaging of Neptune obtained during the 1989 Voyager encounter.

Professor Counselman and colleagues are developing a system to monitor strain accumulation in the crust of the earth regionally and globally. Radio signals from tiny transmitters distributed throughout areas being monitored are relayed by satellites to central processors which determine the positions of the transmitters from the phases of the signals. Tens of thousands of points (e.g. distributed throughout Japan and the state of California to form an earthquake warning system) may be monitored continuously and simultaneously. Proof-of-concept experiments using phase measurements of similar signals transmitted by satellites and received at the monitored earth-surface points have yielded daily strain-measurement precision of 1 part in 50 million.

THOMAS H. JORDAN

DEPARTMENTAL STATISTICS

Students

During the academic year 1991-92, there were 215 undergraduates majoring in mathematics, 162 in Course XVIII, Mathematics, and 53 in Course XVIII-C, Mathematics/Computer Science. Bachelor of Science degrees were awarded to 64 students, 55 in Course XVIII, including the double majors, and nine in Course XVIII-C.

There were a total of 118 graduate students in mathematics, all in the Ph.D. program. This year 25 students received the Ph.D. and two received the master's degree.

Faculty

There were 51 faculty members in the Mathematics Department. The following were on whole or partial leave:

Professor Alexander Beilinson (spring term)
Professor Hung Cheng (spring term)
Professor Richard Dudley (fall term)
Professor Kenneth Hoffman (year) as Executive Director of Mathematical Sciences, Educ. Board of the Natl. Academy of Sciences - Natl. Research Council
Professor David Jerison (year)
Professor Daniel Kleitman (fall term)
Professor F. Thomas Leighton (spring term)
Professor Robert MacPherson (year)
Professor Richard Melrose (spring term)
Associate Professor David Anick (year)
Associate Professor Baruch Awerbuch (spring term)
Assistant Professor Ezra Getzler (spring term)
Assistant Professor Ehud Hrushovski (year)

There were seven Visiting Professorships this year:

Professor Elwyn Berlekamp from the University of California, Berkeley (year)
Professor William Dwyer from the University of Notre Dame (spring term)
Dr. Narendra Karmarkar from AT&T Bell Labs (fall term)
Professor Menachem Magidor from Hebrew University (fall term)
Professor Daniel Quillen from Oxford University (fall term)
Dr. Alexander Razborov from Steklov Mathematical Institute, Moscow (spring term)
Professor Mikhail Shubin from the Institute of New Technologies, Moscow (year).

There was one Visiting Associate Professor, Professor James Fill from John Hopkins University (fall).

FACULTY CHANGES

Retirements and Resignations

Professor Nesmith Ankeny retired from MIT this year.

Associate Professor David Anick resigned from MIT this year.

Associate Professor Baruch Awerbuch resigned from the Mathematics Department and will assume a Principal Research Associate position at the MIT Laboratory for Computer Science.

New Appointments

Dr. Scott Axelrod has accepted an Assistant Professorship appointment; his specialty is mathematical physics.

Dr. Bonnie Berger has accepted an Assistant Professorship of Applied Mathematics; her specialty is theoretical computer science.

Dr. Sergey Fomin will join us as a Visiting Assistant Professor of Applied Mathematics, specialized in combinatorics.

Professor Yuri Manin will join the faculty next year.

Promotions
Dr. Michel Goemans was promoted to Assistant Professor of Applied Mathematics; his field is operations research.

Professor Ehud Hrushovski was promoted to Associate Professor without tenure. His field is mathematical logic.

Honors, Prizes and Awards
Professors George Lusztig and Robert MacPherson were elected to the National Academy of Sciences.

Professor MacPherson was concurrently elected to the American Academy of Arts and Sciences.

Professor Arthur Mattuck was awarded an Inaugural MacVicar Faculty Fellowship in recognition of significant contributions to undergraduate education.

Professor Richard Melrose was awarded a Guggenheim Fellowship.

Professor Steven Kleiman was elected to the Royal Danish Academy of Sciences and Letters.

Assistant Professor Sheldon Chang was selected as an Alfred P. Sloan Research Fellow.

Graduate student Peter Schmidt received the Alfred P. Sloan Doctoral Dissertation Fellowship.

Seniors Christos Athanasiadis and Mikhail Grinberg were awarded the Jon A. Bucsela Prize in Mathematics in recognition of distinguished scholastic achievement in mathematics. Three seniors in mathematics were elected to the national honor society Phi Beta Kappa.

ADMINISTRATION

Professor Robert MacPherson continues as Chairman of the Pure Mathematics Committee following a year's leave of absence. The following committee chairs remain the same:

Professor Alar Toomre - Applied Mathematics Committee
Professor Sy Friedman - 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.

Some fine tuning has strengthened the curriculum. The department has established three two-term calculus sequences: standard, 18.01 & 18.02 Calculus, applied, 18.011 & 18.021 Calculus, and theoretical, 18.012 & 18.022 Calculus. As the students arrive with diverse backgrounds, all but one of the resulting six one-semester courses is offered in the fall, with satisfying enrollments. Freshman seminar offerings are doing well, with an average of three offered each term. The course in algebraic topology, 18.904 Seminar in Topology, is very successful as an undergraduate seminar. The honors version of differential equations, 18.032 Differential Equations, continues to be successful also. Professor James Munkres will rejuvenate the 18.950 Elementary Differential Geometry & Differential Topology and 18.710 Abstract Linear Algebra courses next year.

Efforts continue toward the improvement of the quality of teaching. The Dean of Science has offered a program to videotape faculty and Instructors. The department's videotaping program of graduate student teachers will be back in full swing next fall. Professors Friedman and Mattuck will lead in the critiquing of the videotapes. Maureen Horgan and Peggy Enders from the office of the Dean for Undergraduate Education have initiated a series of meetings both to orient and obtain feedback from recitation Instructors, and to increase communication among faculty lecturing on the core science courses at MIT.

One of the important topics of discussion at these meetings concerns the Math Diagnostic, a precalculus exam given to entering freshmen. The results suggest that our entering freshmen do have serious deficiencies in precalculus and consideration is being given to include a precalculus exam as part of the MIT Requirements. Professor W. Gilbert Strang has agreed to offer a special version of multivariable calculus next fall, 18.02s Calculus, which will include students who performed poorly on the diagnostic.

DAVID J. BENNEY

Department of Physics

During the past year, all major research programs in the Department have remained active and some important new initiatives have been started, as described in the detailed accounts later in this report. The Department has continued to creatively 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 major MIT interdepartmental laboratories. Currently, the Directors of the Laboratory for Nuclear Science (LNS), Bates Linear Accelerator Center, National Magnet Laboratory (NML) and Harrison Spectroscopy Laboratory are members of the Physics Department, as well as the Associate Directors of the Research Laboratory of Electronics (RLE), the Plasma Fusion Center (PFC) and the National Magnet Laboratory (NML). In addition, Professors Robert J. Birgeneau and J. David Litster serve as Dean of the School of Science and Vice President and Dean for Research, respectively. Professor Robert L. Jaffe has been named Chairman-Elect of the Faculty. In 1991-92 the total number of faculty was 83. The following faculty members received promotions: to Associate Professor with Tenure, Edmund Bertschinger, Mehran Kardar and John Tonry; to Associate Professor without Tenure, Katherine Freese, Simon Mochrie, Jonathan Wurtele and Barton Zwiebach. Six new Assistant Professors joined our faculty: Xiangdong Ji, Leonid Levitov, Samir Mathur, Lisa Randall, Paraskevas Sphicas and Xiao-gang Wen. Institute Professor Francis Low is retiring this year. Faculty on leaves or sabbaticals during this year included: Professors Ulrich Becker, George Bekefi, Katherine Freese, Kenneth Johnson, Robert Ledoux, Walter Lewin, Stephan Meyer, David Pritchard, Jean-Pierre Revol, Steven Stahler, and Barton Zwiebach.

A number of faculty received awards during the past year. Professor John Negele was named to the William A. Coolidge Professorship. Professor Alan Guth was named to the Weisskopf Professorship and also received the 1992 Julius Edgar Lilienfeld Prize from the American Physical Society for his outstanding contributions to physics by an individual with exceptional skills in presented lectures to general audiences. Professor Henry Kendall was named to the Julius A. Stratton Professorship. Professors Kendall and Jerome Friedman were elected to the National Academy of Sciences in recognition of their continuing achievements. Professor Jeffrey Goldstone was awarded the Dirac Medal by the International Center for Theoretical Physics. Professor Daniel Kleppner was elected a Fellow of the Optical Society of America. The 1991 Buechner Prize was awarded to Professor John Tonry for his outstanding contributions to the educational program of the Department. Professor John King was awarded the School of Science Teaching Prize for his significant contributions to physics laboratory instruction for more than three decades. Professor Simon Mochrie was named the first recipient of the Michael and Philip Platzman Award, which recognizes the achievements of junior faculty in research. Professors Leonid Levitov and Lisa Randall were awarded Alfred P. Sloan Research Fellowships. Professor Randall was also named an Outstanding Junior Investigator by the Department of Energy. Professor Edmund Bertschinger was awarded the Warner Prize of the American Astronomical Society, given annually to an outstanding astrophysicist under thirty-five years of age. Professor Bruno Coppi was recognized with the Fusion Power Associates Leadership Award. Institute Professor Emeritus Philip Morrison was awarded the Klempke-Roberts Prize of the Astronomical Society of the Pacific for outstanding contributions to the public understanding of astronomy. Two Senior Research Scientists, Dr. T. William Donnelly and Dr. Simon Foner were elected Fellows of the American Physical Society and of the Institute of Electrical and Electronics Engineers (IEEE), respectively. With regard to new appointments, Professor Ernest J. Moniz was named Head of the Physics Department, Professor Stanley Kowalski was named Director of the Bates Laboratory, Professor J. David Litster was appointed as Vice President and Dean for Research, and Professor Robert Redwine was appointed the Director of the Laboratory for Nuclear Science.

The Physics undergraduate students received several awards in 1991. Bryan R. Smith was awarded the Joel Matthew Orloff Undergraduate Research Opportunities Program (UROP) Award. Konstantina Trbovic received the Association of MIT Alumnae Award. Lerothodi Leeuw received an honorable mention for his short story for the Robert A. Boit Writing Prize. Adam H. Wagman received the I. Austin Kelly III Prize for outstanding scholarly essay. Six students were elected to Phi Beta Kappa: Tarik K. Alkasab, David W. Hogg, Adam G. Riess, Fintan D. Ryan, Konstantina Trbovic and Eric A. Woods. Mark D. Messier received the Ragnar and Margaret Naess Music Fund Scholarship as well as the Gregory Tucker Memorial

Prize. Adam H. Wagman received a fellowship from the National Science Foundation. Tarik K. Alkasab received the New England UROP Award as well as the Laya and Jerome B. Wiesner Award.

Several physics graduate students received special recognition during the past year. The Sergio Vasquez Graduate Prize was awarded to Hector Jiminez-Gonzalez. It recognizes outstanding performance in doctoral research by an under-represented minority graduate student. Michael Haggerty received the 1991 Buechner Student Teaching Prize for his accomplishments as an instructor in the Junior Physics Laboratory. The first Alan H. Barrett Prize for excellence in astrophysics, established in memory of Professor Barrett, was awarded to Samuel R. Conner, recognizing his important research in radio astronomy. Alec Sandy received the first Martin Deutsch Graduate Student Award for Excellence. In addition, two physics graduate students Adam Brailove and Darren Garnier, along with three graduate students in the Nuclear Engineering Department, developed a new hands-on physics curriculum for high school studets. They designed twelve experiments which teachers can build for $15 or less, leading to a significant increase in class enrollment in their pilot project.

The James N. Murphy Award for inspired and dedicated service to the Institute by a staff member was given to Ms. Peggy Berkovitz, Graduate Administrator in Physics.

The Department undertook a major study, together with the Planning Office, of long term space needs. The study looked to integrate the need for physics faculty consolidation with the Institute's long range plans for campus development, particularly in the Northeast Sector. Recommendations have been forwarded for consideration.

EDUCATIONAL ACHIEVEMENTS AND INNOVATIONS

The Department has continued to maintain a consistent number of graduate and undergraduate students as well as a relatively constant number of credit units per faculty member. This year the number of undergraduate majors was 220 and the number of graduate students was 311. The number of degrees awarded totaled 57 S.B., 11 S.M., 37 Ph.D.

In the past year, we have moved to institutionalize the successful 8.01X, 8.02X "hands-on" freshman physics sequence introduced in 1989-1990 by Professors Tony French and John King. That is, since the course appears to provide an attractive option for a significant number of freshmen, the Department has assumed responsibility for experimental kit preparation and is assigning other faculty to the course. In addition, the Department has organized a new freshman physics course, 8.01L, which will extend through IAP, thereby providing valuable time for review of essential mathematical and problem-solving skills.

CURRENT RESEARCH

Astrophysics Division

Research in the Astrophysics Division deals with phenomena ranging from the earth's magnetosphere to the most distant quasars. Observational programs involve the collection, analysis and interpretation of data from a wide variety of ground-based and space-based observatories. There are major efforts for the development of new instrumentation to detect cosmic radiation across the electromagnetic spectrum, from radio to gamma rays. Theoretical research is carried out on topics ranging from plasma physics in the solar system, through stellar evolution, to the large scale structure of the universe.

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, such as the German ROSAT telescope. X-ray maps of five clusters of galaxies have been used to constrain the shape of the dark matter distributions, which are found to be significantly rounder than the galaxy distributions. This appears to be consistent with predictions of N-body simulations of cosmic evolution in the cold dark matter scenario. Observations of a distant quasar revealed an energetic X-ray flare lasting only several minutes; this is taken as evidence of relativistic beaming of the quasars high energy radiation. X-ray and optical studies of an interacting binary system containing an accreting white dwarf star have shown it to be an unusual, asynchronous rotator. Systematic studies of the properties of X-ray bursts (caused by thermonuclear flashes on the surfaces of neutron stars or, in one case, spasmodic accretion onto a neutron star) and of quasi-periodic oscillations in the X-ray intensity have been used to constrain possible physical

models of the low-mass X-ray binaries that are believed to cause these phenomena. Our neighbor galaxy, the great Andromeda nebula or M31, has been mapped optically at the Michigan Dartmouth MIT (MDM) observatory in fifty, two-color CCD frames. Data from this study are being used together with a deep X-ray map obtained with ROSAT to identify and classify the ~250 X-ray sources in that galaxy. Optical flashes from gamma ray bursts (detected with the recently launched Gamma Ray Observatory) are being searched for with the Explosive Transient Camera located on Kitt Peak.

Several major instrumentation projects are underway including design and construction of an X-ray CCD camera for the Japanese Astro-D mission, which will be launched in February 1993, the X-ray Timing Explorer, the Advanced X-ray Astrophysics Facility, the Explosive Transient Camera, and the High Energy Transient Experiment. Details are given in the report of the Center for Space Research.

Radio Astronomy

A major activity in the radio astronomy group is the study of gravitational lenses. Monitoring continues of the relative brightness of the two images of the gravitationally lensed quasar, 0957+561 to improve the measurement of the difference in light travel time along the two lines of sight. This can then be used to constrain the Hubble constant. Systematic studies of several lens candidates, including several Einstein Ring sources, combined with lens modeling are being used to understand the properties of the lensing galaxies. A new Einstein ring was found this year as part of the extensive survey for new lenses being carried out with the Very Large Array (VLA) radio telescope.

A separate program involves Very Long Baseline Interferometery (VLBI) observations of dMe stars, dwarf M stars that show evidence for surface activity. The detection of dMe stars on VLBI baselines makes possible the measurement of the position of these stars with high precision, and the astrometric detection of planetary companions may be feasible. Initial observations have investigated the nature of the radio emission, and have identified extragalactic radio sources suitable as positional references for the stars AD Leo, EV Lac, and YZ CMi. First-epoch VLBI astrometric measurements were carried out last June using a VLBI array composed of telescopes in the United States, Spain and Germany. The correlation of the data is complete, and the current effort is the calculation of phase-referenced maps of the dMe stars. Other future techniques for the detection of planetary systems are being explored as part of a broadly based NASA sponsored study. The radio astronomy group is also participating in the Soviet and Japanese space VLBI missions which are scheduled to take place in 1995. Other projects include a search for highly redshifted pregalactic Hydrogen Clouds using a 2000 channel receiver on the giant Arecibo radio telescope in Puerto Rico, and studies of various methods of detecting and observing exoplanetary systems.

Optical Astronomy

The main MIT facility for optical astronomy is the Michigan-Dartmouth-MIT observatory in Arizona, which has 1.3m and 2.4m telescopes 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 gravitational lens candidates from radio surveys, which are described above.

One observational program involves measurement of surface brightness fluctuations which arise from the counting statistics of stars in external galaxies. This can give relative distances accurate to ~5% for these galaxies, which then can be used to derive a value for the Hubble constant and information about the stellar population of the galaxy. Currently this method leads to a value of 82 km/s-Mpc for the Hubble constant, which agrees well with the value found by an independent technique that uses planetary nebulae. Not all other methods agree at present however, so the uncertainty in the true value of the Hubble constant and therefore the age of the universe is not yet fully resolved.

Observations at MDM have revealed the lensing galaxy in a four-image system MG0414, which had not been seen previously. Work also continues on mapping the structure of our own Galaxy using bright carbon stars and Cepheid variables. A major project to probe the large scale structure of the universe is continuing in collaboration with colleagues at several other institutions. Narrow band imaging was performed at MDM of nebulae associated with the endpoints of stellar evolution, supernova remnants and planetary nebulae candidates from a new VLA radio survey of the Milky Way.

There are also two optical astronomy instrumentation projects underway and nearing completion, a modular spectrograph and a large format CCD camera.

Observational Cosmology and Gravitation
Further results from the Cosmic Background Explorer (COBE) Mission have finally shown the presence of a very slight (15 microKelvin) anisotropy in the 3 degree microwave background. The results are consistent with predictions of the inflationary universe model. Partial results from an earlier MIT balloon-borne radiometer operating as a survey instrument with a 3.5 degree beam also give hints of the anisotropy at a still finer angular scale. A new balloon borne payload was just successfully flown to study background fluctuations on still smaller scales caused by electron scattering in the hot plasma in foreground clusters of galaxies.

The Laser-Interferometer Gravitational Wave Observatory (LIGO) is a joint project of Caltech and MIT to develop and construct two 4km baseline gravitational wave interferometers to detect gravitational waves originating from astrophysical sources. Work continues on improving the performance of a 40 meter prototype at Caltech and on the 5 meter interferometer at MIT. Initial construction funding was approved in 1991.

Space Plasma Physics
The Space Plasma Group has continued its analysis of the magnetosphere of Neptune based on data from Voyager II. The spacecraft is now heading toward the termination shock, which is thought to be at a distance of ~70 Astronomical Units from the sun. It will take ~9 years for the spacecraft to reach that distance. Meanwhile, radio and plasma density observations have been used to construct a possible model of 2-3 kHz radio emission which is thought to originate in the termination shock as a result of episodes of unusually intense solar wind.

The new plasma experiment for the WIND spacecraft was completed and delivered to NASA. Launch is expected in the summer/fall of 1993, and preparation for data analysis is underway.

Theoretical Astrophysics
Studies continue 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. Numerical N-body simulations of cosmic evolution with 16M mass points have been run on national supercomputer facilities. The simulations are being "observed" and compared with the present distribution of galaxies to help constrain possible cold dark matter scenarios. Simulations of galaxies and clusters that include both gas and stars are also being carried out and compared with X-ray observations of real clusters.

Work has continued on relativistic plasmas and their applications to quasars and active galactic nuclei. Models are being used to make detailed comparisons of hard X-ray and gamma ray fluxes as measured by the Compton Gamma Ray Observatory. Models of gamma ray bursts due to convective overturn in the interiors of neutron stars are also being studied.

A continuing study is being carried out of the evolution of close binary star systems containing a collapsed star (neutron star, degenerate dwarf or black hole) in which mass transfer is driven by expansion of the companion star as it evolves or by shrinking of the binary system due to gravitational radiation and magnetic braking, or by the effects of X-ray heating of the companion. A detailed investigation has been carried out of the possible scenarios for supernova explosions in interacting binaries, with specific reference to the possible progenitor of supernova 1987A. The chemical composition of the ejecta of close binary supernovae is being studied to look for signatures that could distinguish among various histories. In another study, the effects of X-ray heating on the evolution of compact binaries, including the phenomenon of self-excited stellar winds from the companion star, are being investigated. This, together with a separate consideration of binary star formation by capture in globular clusters, is being used to find possible scenarios for the formation of recycled millisecond pulsars.

ATOMIC, CONDENSED MATTER, AND PLASMA PHYSICS DIVISION

Anisotropy of the Energy Gap in High Temperature Superconductors

The area receiving the most attention in the condensed matter community for the past six years is high temperature superconductivity. Despite the high level of effort, there is still no agreement on a mechanism, much less a complete theory, of this extremely complex phenomenon. It appears, though, that major advances in our understanding may soon be at hand. One central feature of superconductivity is the energy gap that opens up for excitations at the Fermi surface of the metal. Neutron scattering experiments done by an MIT group have given important information about the symmetry of the energy gap.

Neutron scattering was used to study fluctuations of the electronic spins in $La_{2-x}Sr_xCuO_4$. In a conventional superconductor, spin excitations are prohibited at energies below that of the energy gap. However, the new results show that spin excitations in this compound persist at temperatures well below the T_c of 33 K and at energies as low as 1.5 meV, well below the weak coupling BCS gap of ~10 meV. This clearly is inconsistent with conventional BCS s-wave superconductivity in any model in which the electrons on the copper atoms are strongly coupled to the charge carriers. On the other hand, d-wave superconductivity has a gap with nodes at specific points in k-space, and scattering between these could explain the results. The neutron results present by far the most convincing evidence that the superconductivity is unconventional.

Universal Correlations in the Energy Spectra of Quantum Chaotic Systems

There is much current interest in the properties of quantum chaotic systems, that is, systems for which the classical analog exhibits chaotic behavior. The most popular example of quantum chaos is a hydrogen atom in a high magnetic field (MIT is the world leader in the experimental study of this example). Quantum dots on semiconductor interfaces are another example with possible practical applications. The energy spectra of such systems are very complex and it is natural to discuss them in statistical terms. In particular, it was already known that the statistical properties of the spectra at small enough energy scales can be described by the Wigner-Dyson statistics of eigenstates in ensembles of random matrices.

Theorists in the Division concentrated on the magnetization of quantum dots, an example of persistent currents in isolated metallic rings. They studied the dependence of individual energy levels ε in a quantum dot with the topology of a ring as a function of the magnetic (Aharonov-Bohm) flux Φ through the hole. The statistical properties of this system turned out to be quite universal. Later it became clear that the situation was very robust: the same correlation functions were shown to describe the dependence of an energy spectrum of any chaotic system on any external parameter X (external field, shape of the system, etc.). The mean energy level spacing and the mean square of a level energy derivative over X are the only two characteristics which distinguish different systems and different parameters X. All of the statistical properties of the spectra can be rewritten in dimensionless units and turn out to be universal. An analytical approach was developed to evaluate these universal correlation functions. The mean square of a level energy derivative over X was shown to have an important and robust physical meaning. Namely, this quantity determines completely the energy dissipation due to the slow change of X in time.

Application of Massively Parallel Computation to the Study of Semiconductor Surfaces

The recent introduction of massively parallel supercomputer architectures into the mainstream of supercomputer technology paves the way for "theoretical microscope" studies of systems of unprecedented complexity. It is in this vein that an MIT group has successfully completed a series of first principles quantum mechanical calculations to understand the atomic properties of one of the most controversial and widely studied surfaces of a solid. This is the 7 x 7 reconstruction of one of the faces of a silicon crystal. This extremely complicated structure has defied all realistic theoretical modelling in the past. While all comparable earlier efforts peaked at systems with periodic arrays of blocks containing about 100 atoms, the MIT group upped this figure to an unprecedented 700 atoms - enough to reproduce the full complexity of the silicon surface.

Modelling on this scale could eventually offer new insights into how defects and changes in composition alter the atomic structure of solids, and hence their properties. The excitement here is that one can now do first principles calculations on real materials. Beyond that lies the possibility of theoretically designing and discovering completely new materials.

Unexpected Results from the First Tritium Fusion Experiment

The past year saw the first fusion experiment carried out with tritium as a fuel: a deuterium-tritium neutral beam injection experiment in the Joint European Torus (JET) at Culham, England. As is often the case, this pioneering experiment produced unexpected results. Strong electromagnetic radiation was seen at the alpha particle cyclotron frequency and a number of its harmonics. This was unexpected in that the cyclotron radiation from individual alpha particles is known to be weak and confined to a single frequency.

Several years ago theorists at MIT studied instabilities and collective modes in fusion plasmas in which the fuels were spin polarized. (MIT has a strong experimental program on the properties of spin polarized hydrogen and its isotopes. Polarizing fusion fuels has been suggested as a means of increasing the efficiency of the fusion reaction.) The study showed that the distribution of alpha particle velocities in the polarized plasma would be quite anisotropic. A large fraction of the particles would have a velocity parallel to the magnetic field which was less than their velocity perpendicular to the field. Under these circumstances, the alpha particle motion couples strongly to the electrons, creating collective modes which would exhibit strong, anharmonic electromagnetic radiation.

Although the JET experiment did not employ polarized fuels, the alpha particle distribution near the outer edge of the plasma was expected to have a similar anisotropic velocity distribution. Thus, it was realized that the same coupling to collective modes, and resultant enhanced radiation, might occur. Subsequent analysis of the experimental results has confirmed this interpretation. The effect has a practical application in that the alpha particle density is a direct measure of the fusion rate, and this anomalous radiation allows the alpha particle density to be monitored easily.

EXPERIMENTAL NUCLEAR AND PARTICLE PHYSICS DIVISION

Experimental High Energy Physics

Electromagnetic Interactions Group (EMI)

Following the six year construction and installation program of the L3 experiment at the LEP accelerator (Large Electron Position Collider) at the European Center for Nuclear Research Center (CERN) in Geneva, Switzerland, the Electromagnetic Interaction Group (EMI) led by Professor Samuel C. C. Ting has been taking data since the machine first became operational in the summer of 1989. To date 43 scientific papers from L3 have been published including the first publication from LEP. L3 is the largest of the four LEP detectors and is distinct from the other detectors in its design and physics objectives. L3 is an ultra precise detector built with state of the art technology to study photons, muons and electrons with unprecedented accuracy. Collaborating with the MIT/LNS/EMI group on L3 is an international consortium of 510 physicists from 44 institutes and 13 different countries. It represents the first large scale high energy physics experiment in which scientists from the United States, the former Soviet Union, China, and India, work together with the strong support of their respective governments. As in the past twenty five years, the EMI group continues to bear the leading responsibility for the design, construction, installation, execution, and data analyses of all its experiments.

The LEP machine has been operating at a luminosity of $2X10^{31}$ $cm^{-2}sec^{-1}$. To date L3 has collected and analyzed more than 500k Z^0 particles (the carrier of the electroweak force) and with this data sample have been able to carry out many indepth studies, among which are the following: -L3 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, finding

The mass of Z:	$M_Z = 91.184 \pm 0.021$ GeV, and
The total width of Z:	$\Gamma_z = 2.502 \pm 0.010 \pm 0.005$ GeV
The hadron width of Z:	$\Gamma_{had} = 1.742 \pm 0.013$ GeV.

-In the framework of the Standard Model, L3 showed that there are only three kinds of neutrinos in the universe (3.07 ± 0.07).

-L3 set limits on the mass of the Top quark ($M_t = 186 \; ^{+33}_{-42} \pm 14$ GeV).

-In the search for new particles, L3 set limits on the mass of the charged Higgs and neutral Higgs boson ($M_{H^0} > 52.0$ GeV and $M_{H^\pm} > 44$ GeV at 95% c.l.) as well as Supersymmetric particles (scalar muons,

scalar electrons, winos, and scalar leptoquarks) and New Charged and Neutral leptons (excited electrons, muons, taus and neutrinos). In all cases, a lower limit > 41 GeV at 95% c.l. has been obtained.

-L3 determined that electrons, muons and taus all have a radius smaller than 10^{-17} inches.

-In the physics of heavy quarks, $B^0 - \bar{B}^0$ mixing and b quark asymmetries have been studied. L3 has uniquely observed the reaction $Z^0 \rightarrow B\ \bar{B}$ in which B changes to $\bar{B}$ with a probability of X_B. The signature of this phenomenon is the observation of two same-sign opposite-side high-p⊥ leptons. L3 obtained

$$X_B = 0.121 \pm 0.017 \pm 0.006$$

-The strong coupling constant α_s has been measured ($\alpha_s = 0.124 \pm 0.006$). L3 determined that all quarks have a radius smaller than 10^{-17} inches.

-L3 made the most precise measurements to date on the neutral current vector g_V and axial vector g_A coupling constants, finding

$$\bar{g}_V = -0.043 \pm 0.007$$

and

$$\bar{g}_A = -0.4993 \pm 0.0016.$$

L3 plans to continue the search for new particles and physics phenomena on the frontier of physics research. LEP is planning to double its luminosity in 1991/1992 yielding 10^6 Z^0's for L3 to analyze in 1992. The luminosity will continue to increase and by 1995 LEP will cross the $W^+ W^-$ production threshold (LEP200). It is at these highest LEP luminosities that the unique advantages of the L3 detector in its design, precision performance and physics potential will be fulfilled.

Collider Detector Facility (CDF) Group

The group is participating in the Collider Detector Facility (CDF) experiment at the Fermi National Accelerator Laboratory (FNAL), currently the highest-energy accelerator in the world. The CDF experiment is a collaboration of 30 institutions from the U.S., Japan and Italy, studying proton-antiproton ($p\bar{p}$) collisions at a center of mass energy of 1.8 TeV. Briefly, the aims of the CDF physics program are:

By far the most important objective is the discovery of the top quark. Previous work with the UA1 experiment at CERN has put a limit on the mass of the top quark of $M_{top} > 60$ GeV. More recent results by CDF, based on 4.5 pb^{-1}, have constrained $M_{top} > 91$ GeV. The latest results from the LEP accelerator at CERN, when combined with the precise measurement of the mass of the W boson, again from CDF, seem to indicate that the top mass must lie somewhere between 100 and 200 GeV, for (a) the Standard model to be correct and (b) for all the results from different experiments to be in agreement with each other. Beginning in May 1992, the CDF experiment started a new data-taking period, in order to accumulate another 100 pb^{-1}. With this increase in statistics, CDF should be sensitive to top quark masses up to 170 GeV.

Study of the second-heaviest quark, the b-quark, and its mesons. The cross-section for b-production in $p\bar{p}$ collisions is very large. CDF has thus managed to study not only the traditional semi-leptonic decays of the b-quark, but also exclusive decay modes containing a J/ψ. Up to now, the study of heavy-quark mesons has been monopolized by electron-positron colliders. With the expected increase in statistics from the coming runs, and the use of a recently installed silicon vertex detector, CDF should be able to discover baryons containing the b quark, the remaining b mesons, and also measure b-meson mixing to a greater precision.

The study of the W and Z intermediate vector bosons, discovered in a previous experiment, UA1 at CERN, in which MIT participated, is a continuing endeavor for the CDF experiment. An extremely important measurement is that of the mass of the W boson. If the top is discovered, then this mass measurement will

give a prediction for the mass of the Higgs boson. Until the LEP accelerator is upgraded in energy, the FNAL collider will be unique in that it is the only accelerator capable of producing W bosons.
The study of high-P_t (transverse momentum) jets has so far delivered very stringent limits on the energy scale for compositeness (i.e. quark substructure) hypotheses. Since the FNAL collider will be the highest-energy machine in the world until either the LHC or SSC accelerators are built, it is the ideal place to search for any compositeness signals and, if none are found, to increase the limit on the energy scale for compositeness.

The above list is by no means exhaustive. There is a host of other subjects (supersymmetry, boson-boson interactions, magnetic moments) that can be studied. The above represent only the most important "short-term" goals for the CDF physics program.

The Accelerator Physics Collaboration
The Accelerator Physics Collaboration (APC) Group is conducting experimental research at the Gran Sasso Laboratory (GSL) at L'Aquila, Italy, Brookhaven National Laboratory, and the SSC Laboratory in Texas.

The experiment in GSL, which is the world's largest underground laboratory, will study particle physics and astrophysics problems. The particle physics problems are related to the possibility of a new type of particle being emitted from Cygnus X-3. These studies could confirm emission of such particles and provide information on the mechanisms involved and the properties of the source. This experiment can also search for neutrino oscillations. The Group will also study the production of solar neutrinos and will measure the yearly rate of collapsing stars in the universe. Another objective is the search for point sources in the universe emitting high energy neutrinos.

The Group has joined a Brookhaven National Laboratory experiment to study the creation of strangelets which are particles that contain more than three quarks with a large number of the quarks having strange flavor. This experiment will put strong constraints on the parameters involved in QCD theory.

The Group has joined the GEM Collaboration at the SSC Laboratory. We have the responsibility for the first level muon trigger using Resistive Plate Counters.

The Counter Spark Chamber Group
The Counter Spark Chamber group is continuing the development and utilization of the Stanford Large Detector (SLD) at the Stanford Linear Accelerator. The hardware contribution of the CSC Group was the construction of the Warm Iron Calorimeter and Muon Detector, which is now complete. The first data with a polarized electron beam has been taken. The CSC Group is looking forward to performing an incisive test of the Standard Model, via the measurement of the difference in the e^+ e^- production of fermions with left and right circularly polarized beams.

The group continues its involvement in the deep inelastic scattering of muons off nuclei at Fermilab in an effort to understand the formation process of hadrons.

The CSC Group has undertaken three new initiatives directed toward the longer term future, they are:

Development of a detector for the relativistic heavy ion collider (RHIC) which will be built at BNL by the middle 90's. A proposal has been submitted in collaboration with the heavy ion group and is awaiting action by BNL.

Participation in the preparation of proposal for a major detector for Superconducting Super Collider. The group is active and will take a major role in the design and development of the so called "GEM detector" for the SSC. This detector is planned to have superior lepton detection capability. In this connection the group has undertaken muon detector research and development.

The group is participating in the CDF proton-antiproton collider experiment at FNAL in collaboration with the UAl group (see the section "CDF Group" for a more complete description)

Lepton Quark Studies (LQS)

The LQS group is collaborating on the SLD experiment on the Stanford Linear Collider (SLC) at the Stanford Linear Accelerator Center (SLAC). The group is presently participating in data runs, with a polarized electron beam. This polarized electron beam will enable the study of the production of polarized Z-Bosons with left- and right-handed polarized electrons, allowing tests of the present gauge theory with unprecedented precision. In addition to this novel experiment, the group is a member of a U.S. - Chinese collaboration whose aim is to exploit high statistics studies of e^+e^- interactions in the 3 to 5 GeV energy region with the Beijing Spectrometer situated at the Beijing Electron Positron Collider (BEPC) at the Institute for High Energy Physics (IHEP) in Beijing; a follow-up of very fruitful experiments carried out at SPEAR, SLAC's former storage ring collider facility, during 1982-89. This collaboration has just completed a measurement of the Tau-Lepton mass, finding it to be lower than the present world's average by two standard deviations and with an order of magnitude better precision. The value of the Tau-Lepton mass is important in understanding a small discrepancy when relating it to the decay branching ratio and lifetime, within the framework of the present standard gauge model.

The group is continuing its effort in a U.S. collaboration to participate in a possible future e^+ e^- international facility operating in the SPEAR energy region known as the Tau-Charm Factory. This facility is envisioned to provide event rates 100 times and 1000 times more than BEPC and SPEAR, respectively, and equipped with a high precision spectrometer, allowing for continued studies of charmed mesons, charmonium states and properties of the Tau-Lepton.

EXPERIMENTAL NUCLEAR PHYSICS

Relativistic Heavy-Ion Physics (HI)

The Heavy-ion Group is a large part of the E802 collaboration, which has constructed a multi-particle spectrometer that can measure the reaction products produced in collisions induced by the 235 GeV oxygen, 412 GeV silicon, and 2.3 TeV gold beams that have recently become available at Brookhaven National Laboratory Tandem/AGS accelerator facility (unique in the U. S.). Using these beams, collisions with heavy target nuclei, from aluminum to gold, offer far higher matter/energy densities than heretofore studied, approximating conditions that may have occurred during the initial expansion of the universe. In each central collision hundreds of particles are produced. Analysis of the produced particle multiplicity and transverse energy flow, as a function of a target nuclear size, indicates that the projectiles, even at this very high energy, are indeed stopping during central collisions with the largest nuclei, producing energy densities several-fold higher than in normal nuclear matter. Analysis of the spectrometer data has yielded the provocative result that the production of positive strange mesons (K^+) relative to normal π^+ mesons is threefold enhanced compared to proton induced reactions. We are just now analyzing data obtained from the Spring 1991 and 1992 runs that utilized a newly installed "smart" trigger. By performing particle identification within 10 msec this allows on-line event selection, thereby increasing our data sample for K^+ by over a factor of 10. The tracking detector system is being upgraded in order to exploit the much heavier and energetic gold beams that have just become available, allowing one to reach even higher matter/energy densities. Furthermore, the MIT group has received a favorable response to a Letter of Intent, with Prof. Wit Busza as spokesman, for the PHOBOS detector for the Relativistic Heavy-Ion Collider (RHIC), which is now under construction at Brookhaven. This machine will have almost 40 TeV center-of-mass energy for gold-gold collisions beginning in 1997. The detector consists of two spectrometer arms consisting of 10 planes of Si detectors located in pairs of superconducting coils. The readout electronics consist of custom designed integrated circuits being developed at MIT-LNS. The whole apparatus is very compact, about 1m in size, and will be built at a cost of $5M.

Intermediate Energy Nuclear Physics and the Bates Linear Accelerator Center

About 20 MIT graduate students carried out research projects with the medium energy nuclear physics group during the past year. Experiment were performed at the MIT-Bates Linear Accelerator Center and at several other facilities.

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. Nucleon structure is being studied in several ways. The neutron charge distribution is essentially unknown. Two complementary experiments recently carried out at Bates have provided the first direct measurements. One involved the scattering of longitudinally polarized electrons from polarized ^{3}He nuclei. The second involved a double scattering experiment which measured the polarization transfer to neutrons knocked out quasielastically from the deuteron. Another program will study the deformation of protons. All of these efforts require major technical developments and involve novel use of polarization observables The polarized ^{3}He target development provides the basis for our leading role in a major experiment planned at DESY (Hamburg), which will measure proton and neutron quark spin distributions. It has also been used in an experiment at the Indiana University Cyclotron Facility exploiting spin observables in proton scattering. These data have demonstrated the power of polarized internal targets in this energy regime.

Electron-proton Coincidence Experiments

Electron-proton coincidence experiments continue to be an important program at Bates. The emphasis has been on the study of this reaction process to high momentum transfers and high missing energies. A set of pioneering measurements, aimed at precision studies of the deuteron and ^{12}C, were initiated last year. These involved the use of an out-of-plane spectrometer, one of five under construction, to measure unique electromagnetic response functions. It included the first-ever measurement of the so-called fifth response function which also requires use of a polarized beam. The MIT group, which has spearheaded the coincidence program at Bates, is also playing a key role in the development of the Hall A high resolution spectrometer systems at CEBAF. When this new 4 GeV CW accelerator is operational, expected in 1996, it will provide an important extension to the capabilities developed and pioneered at Bates over the past decade. A high energy electron-proton coincidence experiment was recently carried out by an MIT group at SLAC in a study of "color-transparency". The motivation was to probe the evolution of struck quarks to nucleons as they exit the nuclear medium. The data are now being analyzed

Parity

Parity non-conservation, a violation of reflection symmetry in nature, arises from the weak force. The very small difference (less than one part per million) in scattering electrons in two different polarization states from a spherical nucleus was measured at Bates. The difference was found to be consistent with that expected in the Standard Model of elementary interactions. The experiment set new standards for accuracy. A follow-up experiment will measure parity violation in electron-proton scattering. It is in an advanced development stage. The result will provide new information on the importance of strange quarks in the structure of the nucleon.

Pion Physics

Several experiments on pion-induced reactions have been carried out at the Los Alamos Meson Physics Facility (LAMPF) and at the Paul Scherrer Institute (PSI), with the goal of elucidating hadronic reaction mechanisms. At LAMPF, a program to study inclusive pion scattering, single charge exchange, and double charge exchange in light nuclei (^{3}He through ^{12}C) is nearing completion. A new, high-resolution neutral meson spectrometer is under construction to extend the studies of the ($\pi^{\pm}$, π^0) reactions. At PSI, a large acceptance (nearly 4π steradians) detector system has been constructed primarily for the purpose of investigating pion absorption, in particular those processes leading to the emission of several nucleons. Data have been obtained on absorption in ^{3}He, ^{4}He, nitrogen, and argon, and are expected to yield information on possible new physics in the region of non-perturbative QCD.

Bates 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 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 is scheduled to be completed in FY93.

In the internal target mode, the electrons are circulated thousands of times through a windowless gas storage 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 now make it feasible to produce gases of polarized nuclei of sufficient thickness for internal target use. Such internal target experiments, representing a significant departure from the traditional experimental configuration in electronuclear physics, will require innovative developments advancing both physics and technology.The target technology using polarized 3He was recently tested successfully by the MIT group at IUCF. A major new detector called BLAST (Bates Large Acceptance Spectrometer Toroid) has been designed, in collaboration with scientists from eight other institutions. This large acceptance detectoris matched to the luminosity and polarized target requirements of the SHR internal target facility. Peer reviews have provided strong scientific endorsement of the concept. Funding is being sought for construction starting in FY94.

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 successive injection 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, measuring the nuclear pion distribution near threshold, and studying the electromagnetic structure of nucleons. Newly developed instrumentation, such as out-of-plane spectometers and a focal plane polarimeter, will be important for exploiting the CW beam. These instruments are in the testing stage.

NUCLEAR AND PARTICLE THEORY DIVISION

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 manifestation in nuclei, nuclear many-body theory, reaction 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 in the area of lattice gauge theory, which provides a unique tool to solve, rather than model, QCD. Lattice calculations of wave functions and quark correlation functions for the pion, rho, and proton agree with experimental charge radii, demonstrate that only half the spatial extent of hadrons arise from the three-quark or quark-antiquark component of their wave function, and provide new insight into the the limitations of bag and Skyrme models. A variety of analytic approaches to QCD are being explored, ranging from classical solutions to mean field and variational calculations. An effective theory of confinement has been developed in collaboration with the particle theory group which provides a new understanding of confinement in terms of the propagation of quarks in a fluctuating color field and the properties of QCD at high temperature, relevant to relativistic heavy ion experiments, have been studied.

With the addition of a new faculty member, a major research initiative has been undertaken in the study of nuclear and nucleon structure functions. In collaboration with the particle theory group, a complete classification of spin-dependent structure functions has been carried out, and new experiments have been proposed to measure many of them. In addition, independently, the first comprehensive analysis was made of all the parity-violating structure functions which can be measured at high energy where weak and electromagnetic contributions become comparable, leading to the possibility of separating the valence and sea contributions to g_1 at HERA. A fundamental investigation relating structure functions to hadron wave functions on the light cone has also been undertaken.

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. Efforts have continued to understand the nature of periodic solutions in multi-dimensional classical systems and their implications for quantum chaos and to calculate periodic solutions for physical processes. Path integral techniques, which have previously been used by this group for a wide variety of nuclear many-body problems, have been applied to the nuclear response function. The distribution of momentum in deformed nuclei has been studied in models and in mean field theory and shown to be deformation independent. Several new approaches are being applied to nuclear many-body theory, including scattering theory and perturbation theory in a time-dependent basis and application of the doorway state method to ground state properties. Developments in reaction theory include understanding the origin of friction in the optical model, derivation of a simple approximation for highly inelastic low energy collisions, and study of interference effects in the passage of a fast particle through a nucleus.

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 new Bates South Hall Ring. 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 systematic evaluation of electroweak radiative corrections. A new thrust has been investigation of the use of neutral current probes to study the strange quark content of the nucleon. Studies of the nuclear response function have addressed new approximation schemes, development of a systematic expansion for the y-scaling regime, and the study of relativistic effects.

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 and QCD. A significant new development has been the discovery of a new class of chirally-odd quark structure functions. Since these structure functions cannot be measured in chirally-conserving deep inelastic lepton scattering, new experiments have been proposed to measure them in polarized proton-proton collisions and in direct photon production. Two-baryon interactions have been studied using a hybrid bag model with external meson fields, with the goal of exploring coupled channel effects and possible exotic resonances. The possibility of producing exotic resonances in pion-nucleus scattering has also been explored. 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. Fundamental studies of hadronic interactions relevant to the physics of relativistic heavy ion collisions include calculation of J/ψ production from nuclei, study of the propagation of color charges and dipoles and of the production of dilepton pairs in the quark-gluon plasma, and investigation of the freezout of hadrons from hot, dense matter.

Particle Theory

Research in particle theory at MIT seeks to extend and unify our understanding of the fundamental constituents of matter and the theory which governs them. During this past year, significant advances have been made in the areas of particle phenomenology, cosmology, and the theory of fields and strings, as well as in the more general areas of quantum mechanics and mathematical physics.

Spin dependent structure functions, which specify the distribution of quarks and gluons in a hadron of a specific spin orientation, are expected to become accessible experimentally and are therefore of particular importance in particle phenomenology. They have been a continuing source of interest to members of our group and the nuclear theory group and a topic of fruitful collaboration. In the context of the parton model, it has now been understood how to completely specify the full set of independent information about particle structure that can be obtained from measurements in which spins are polarized transverse to the direction of the incident particle. In addition, it has been shown how to exploit semi-inclusive lepton scattering as a new source of information. This new understanding will be crucial in planning future experiments.

In collaboration with members of the nuclear group, a new model has been developed for the description of hadron structure. This model is motivated by the understanding gained from lattice gauge calculations about the dominant role that should be played by the non-perturbative enforcement of the color version of Gauss's law. In addition, a new formulation of Yang--Mills field theories promises a different insight into the consequences of the non-Abelian aspects of this law.

Investigations at the interface of quantum field theory and cosmology have continued to address the fundamental problem of how fluctuations and density perturbations in the inflationary phase of the big bang generate the large scale structure observed in the present universe. The recent COBE observation of fluctuations in the microwave background highlight the importance of this problem and provides a new impetus towards its resolution.

To deepen our understanding of general relativity, the existence of "time machines" or closed time-like paths has been investigated in gravity theories in two space dimensions. Although such paths exist as formal solutions, in the cases which have been studied, the systems which allow such solutions are shown to be unphysical or impossible to create from a physical initial condition. Another topic under study at the interface of particle physics and cosmology is the problem of baryon number violation as the scale of the weak interaction versus a violation at the grand unified scale.

In quantum field theory, the method of "differential regularization" for carrying out the ancient task of regularizing and renormalizing divergent Feynman diagrams has been developed. Up to now there has been no such single method which was effective for all interactions, and this defect has now been remedied.

Understanding the role of topology and quantum symmetry breaking in field theory is an area in which members of this group have had a continuing interest and made seminal contributions. Current work addresses field theories in two space dimensions, with particular emphasis on quantum gravity and the theory of the novel vortex-like structures known as anyons which are believed to play an important role in physical two-dimensional condensed matter problems.

Research in the theory of strings and related problems has flourished with the infusion of new faculty in this area. The general field theory of closed strings developed previously has now been applied to a solvable model, and effort is underway to remove its background field dependence. Symmetry breaking in topological field theories has been investigated and the roughening of the two-dimensional world sheet has been clarified by the proof that the surface is self-similar. The study of thermodynamics in string theory has led to the study of the role of temperature in gravity theory and addresses the problem of the Hawking temperature and radiation from black holes.

With the addition of a new faculty member, studies of the phenomenological consequences of the standard model are now being pursued in new directions, including both precision tests of the electroweak interaction and study of the phenomenological implications of possible extensions of the standard model. Such studies will be crucial to the physics of present and future experimental programs at Fermilab, LEP, HERA, SSC, and the LHC.

Much of the vitality of the Center for Theoretical Physics arises from broad interests in general problems in theoretical physics. Thus, nuclear and particle theorists have also addressed a variety of general topics in mathematical physics, field theory, quantum mechanics, many-body theory, statistical mechanics, and astrophysics. Recent examples range from the study of novel quantum mechanical bound states for particles in twisted tubes to an analysis of the instabilities in systems with long-range interactions like plasmas or stellar systems.

ERNEST J. MONIZ

Center for Cancer Research

The Center for Cancer Research was established in 1973 to study fundamental biological processes related to the human disease of cancer. The goals of the Center's research can be generally stated as developing an understanding of (1) the genetic and molecular basis of cancer, (2) how alterations in cellular processes affect cell growth and behavior, and (3) how the immune system develops and recognizes antigens. These goals are related to the Center's major research programs in oncogenes and mammalian genetics, molecular, cellular and developmental biology, and immunology. Currently 183 people work in the Center, distributed among the research laboratories of 11 faculty.

During the past year three new faculty have been recruited. Dr. Hidde Ploegh, a cellular immunologist, and Dr. Tyler Jacks, who works on tumor suppressor genes, have already set up their labs in the Center. Dr. Jun Liu, a biochemist who has been involved in elucidating the signalling pathways affected by immune suppressant drugs such as cyclosporin, will join the Center during the coming year.

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, some faculty salaries, and central research facilities (i.e. glass washing facility, specialized laboratories and partial support for new faculty) is a Center core grant from the National Cancer Institute. this grant was renewed in 1990 and its current term extends to April 30, 1995. The Center's success in attracting grant support is a reflection of the overall excellence of the research and educational activities of its faculty members. In addition to the core grant, the Center's faculty have a total of 42 fully funded projects not including over half a million dollars of competitive support in fellowships for postgraduate studies. The Center has recently completed renovations of 2,253 sq. ft. of space for research in immunology and vertebrate development. This renovation was partially supported by a construction grant from the National Cancer Institute.

Several groups in the Center study the identity and function of oncogenes. This work includes the recent identification of the Wilms' tumor oncogene as well as basic molecular studies on other oncogenes that regulate gene expression controlling the cell cycle and tumor growth. Another focus is on the biochemical mechanisms controlling RNA transcription and splicing, including studies of genes of the AIDS virus, HIV.

The immunologists in the Center study the development of cytotoxic and helper T lymphocytes, their antigen-specific receptors, and the molecular mechanisms of antigen presentation. Since the immune response to tumors is poorly understood, these basic studies are crucial to a more profound analysis of tumor rejection. Immune cells can destroy cancer cells and it may be possible to stimulate this process.

The cell biologists study cell surface proteins involved in cellular adhesion and migration, as well as cytoskeletal proteins involved in cell motility and shape. Alterations in cell adhesion proteins contribute to the malignant phenotype of tumor cells. These proteins as well as cytoskeletal proteins are important targets for antitumor drugs, and deeper understanding of their structure and function should contribute to better therapeutic agents.

Since the cellular processes of development and cancer have much in common, useful insights into the behavior of tumor cells can be obtained from studies of normal embryos; several projects in the Center focus on developmental processes. Recent advances in the generation of transgenic mice and mice with mutations in targeted genes are being exploited to investigate the roles of a variety of proteins important in tumorigenesis, including oncogene proteins, cell adhesion receptors, T-cell receptors and protein kinases.

Dr. Nancy Hopkins has initiated a program studying the embryonic development of a vertebrate organism, the zebra fish. This fish matures rapidly and a single female can generate more than 10,000 eggs per month making it a very promising genetic system. Variants of this fish generate high incidences of tumors. Dr. Hopkins' newly initiated research on this interesting system will be performed in some of the recently renovated space.

Major research advances in the past year include; identification of the gene and mutations leading to myotonic dystrophy (Housman), identification of a gene involved in learning and memory (Tonegawa) by genetic engineering in mice and the generation of strains of mice defective in their immune system (Tonegawa) in tumor suppressor genes (Jacks) and in crucial cell adhesion molecules (Hynes).

Faculty members in the Center have played a critical role in developing the Program of Excellence for research in heart disease (Drs. Hynes, Housman and H. Earl Ruley) and the Human Genome Center (Dr. Housman). Both of these multi-investigator research programs complement the Center's research on cancer and greatly strengthen its effectiveness. Furthermore, during this past six years the Center has had an important role in advancing our understanding of human cancer which will ultimately result in more effective therapies. The Center has a strong basis to extend this record of accomplishments and the faculty, research fellows, students, support staff and administration are excited about the opportunity.

Major honors received by faculty of the Center during this past year were: Dr. Phillips Robbins was elected member of the Institute of Medicine, National Academy of Sciences and Dr. Phillip Sharp was appointed to the Salvador E. Luria Professorship at MIT.

The faculty of the Center fulfill critical roles in the educational programs of the Department of Biology. Our colleague, Dr. Sharp has served as Head of the Department for the past year succeeding Dr. Hynes. Dr. Frank Solomon serves as Chairman of the Department's Graduate Program. Both Drs. Hynes and Sharp are involved in the planning of the new biology building now under construction. Dr. Hopkins is involved in development of the new Biology requirement.

In historical perspective, the past six-year period has been an important transitional period for the Center for Cancer Research. It commenced with Dr. Sharp assuming the Directorship of the Center from Dr. Salvador Luria and the departure from the Center of Professors David Baltimore, Robert Weinberg and Richard Mulligan to the then newly established Whitehead Institute at MIT. Also, during this period of transition, the research programs of the Center grew and evolved. Two Center faculty members were appointed Investigators of the Howard Hughes Medical Institute (Hynes and Tonegawa). Resources from the Center and the Howard Hughes Medical Institute were combined to created state-of-the-art core facilities for analysis of cell populations and synthesis and sequencing of biological polymers. research space in the Center was expanded and renovated to accommodate the growth in programs of its faculty. Dr. Hynes took over as Director a year ago. His major initial task was the recruiting of new faculty. As mentioned, three were recruited this year and 2-3 more appointments are expected in this coming year.

A major strength of the Center remains its attractiveness as an environment for the training of young scientists. The Center has 31 graduate and undergraduate students and 59 postdoctoral fellows/associates. The Center also benefited from a number of international faculty-rank visitors during the past year: In Dr. Tonegawa's laboratory: Drs. Stefan H. E. Kaufman (Institut fur Microbiologie der Universitat Ulm, Germany), Werner Haas (Hoffman La Roche Institute, Basel, Switzerland), Antonio Coutinho (Institut Pastuer, Paris, France), Hidde Ploegh (The Netherlands Cancer Institute, Amsterdam, The Netherlands), Charles M. Steinberg (Basel Institute for Immunology, Basel, Switzerland). In Dr. Housman's laboratory: Guenther Heinrich (Sandoz Corporation, Basel, Switzerland), Hiroyuki Aburatani (Tokyo University, Tokyo, Japan), Hiromichi Ishikawa (Keio University, Japan). In Dr. Phillips W. Robbins' laboratory: Drs. Neil Gow (Aberdeen University, Scotland) and Annette Herscovics (McGill University, Montreal, Canada). In Dr. Brent Cochran's laboratory: Maciej Kotechi (Institute of Human Genetics, Poznan, Poland). In addition, a number of physicians who have affiliations with teaching hospitals in the Boston are are in training in the various laboratories of the Center: Drs. Barbara Shephard and Cynthia Kellogg, Tufts New England Medical Center; Drs. David Fisher and Daniel Haber, Fellows in Medical Oncology, Harvard Medical School and the Dana Farber Institute; Dr. David Potter, Hematology Fellow, Brigham & Women's Hospital and Harvard Medical School; Dr. Michael Rabin, Beth Israel.

Richard O. Hynes
Director and Professor of Biology

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 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; theoretical and experimental space plasma physics; planetary surfaces and atmospheres; and the space life sciences. The current and near-future NASA flight program contains a number of missions in which CSR is heavily involved: the Voyager mission now beyond the farthest planet, the Magellan Venus Radar Mapper mission, the Cosmic Background Explorer (COBE), the Advanced X-ray Astrophysics Facility (AXAF), the X-ray Timing Explorer (XTE), the Space Transportation System (Shuttle) Spacelab series, and an investigation of Earth's plasma environment as part of the International Solar Terrestrial Physics Program (ISTP). Two other "mission-of-opportunity" programs, in which CSR is playing a crucial role, are ASTRO-D, a Japanese X-ray satellite for which CSR is supplying an imaging detector, and the High-Energy-Transient Experiment (HETE), a small, inexpensive satellite under MIT's direct control. CSR also supports investigators in the Space Engineering Research Center in carrying out flight experiments. CSR administers 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 (A&A 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 German ROSAT X-ray telescope, launched in May of 1990 as well as archival studies of data from the Japanese satellite GINGA, and previous US and European X-ray missions.

Professor Hale Bradt, Dr. Ronald Remillard and students continue to study x-ray and optical properties of sources from their catalog of identified HEAO-1 sources. Individual objects include active galactic nuclei and cataclysmic variables. Bradt and Remillard are members of the ROSAT Galactic Plane Survey team, and are actively carrying out optical identifications of these objects at the MDM observatory. Professor Claude Canizares, Dr. Thomas Markert and collaborators are completing a major study of the chemical composition of a supernova remnant in the Large Magellanic Cloud, which is found to be extremely rich in oxygen. Canizares and a student have used Einstein Observatory observations of 5 clusters of galaxies to constrain the shape of the dark matter distribution. They find that the dark matter distribution is significantly less flattened than the galaxy distribution. They are now performing a similar study of elliptical galaxies with ROSAT data, together with Professor Paul Schechter. Professor Walter Lewin and his graduate student have made extensive optical observations of the galaxy M31 and are identifying the ~250 sources found in a deep ROSAT observation. The M31 ROSAT observations are made in collaboration with scientists from Germany and Holland. Lewin has also been studying low-mass X-ray binaries using ROSAT and the Japanese observatory GINGA. Together with his Japanese and Dutch collaborators, Lewin continues to probe the phenomena of X-ray bursts and quasiperiodic oscillations. Professors George Clark and Saul Rappaport and their students, working in collaboration with colleagues at the Institute of Space and Aeronautical Sciences (ISAS) in Tokyo, continue studying the atmospheric and wind structures of the companion stars of X-ray pulsars using GINGA. Dr George Ricker and his students are carrying out an extensive X-ray study of gamma ray burst sources with the ROSAT satellite in an attempt to identify the origin of these mysterious sources.

Advanced X-ray Astrophysics Facility (AXAF). AXAF is a major NASA mission of the "great observatory" series, scheduled for launch in 1998. The mission is undergoing a major restructuring, which preserves two of the instruments being designed at MIT, the High-Energy Transmission Grating Spectrometer (HETG) and the AXAF Charge-Coupled Device (CCD) Imaging Spectrometer (ACIS). The Bragg Crystal Spectrometer was not selected for flight on the reconfigured AXAF and has been terminated. The HETG represents a collaboration of Professor Canizares and his group at CSR with Professor Henry I. Smith (EECS) and his Submicron Structures Laboratory. The group continues to develop techniques for fabricating large numbers of 0.2-μm-period gratings having very high uniformity. This year they installed a silicon nitride facility and initiated purchase of a high intensity X-ray lithography machine. Many of the processes required to fabricate and measure gratings to the desired tolerance are now in place. BCS definition, under Professor Canizares, has continued technology development activities leading toward ultra-low leak rate thin membranes. A group under Dr. George Ricker (CSR), Deputy Principal Investigator for ACIS, has continued collaboration with the Micro-Electronics group of the MIT Lincoln Laboratory to develop radiation-hardened X-ray CCDs having quantum efficiencies of better than 50 percent

over the 2- to 6-keV energy range. Noise levels equivalent to the effects of fewer than 2 electrons allow a spectral resolution of better than 120 eV (full width at half maximum) to be achieved at 6 keV, and permit low energy response extending to below 0.5 keV. Recent progress has also been obtained with thinned, backside illuminated devices that gave improved efficiency at the lower energies.

AXAF Science Center. CSR is the junior partner, together with the Smithsonian Astrophysical Observatory, in the AXAF Science Center. This center is charged with scientific oversight of pre-launch and post-launch operations of AXAF. Professor Canizares is Associate Director for MIT and acting head of the Science Support Division.

ASTRO-D Mission. This program is a joint undertaking of CSR (through NASA) and ISAS (in Japan). Under the terms of the international agreement, CSR is providing a focal-plane instrument incorporating two arrays of ultra-low-noise CCD X-ray detectors, for launch on a Mu-3-SII rocket by ISAS from Kagoshima Space Center in Japan in February 1993. Dr. Ricker is the Principal Investigator for the ASTRO-D CCD instrument and, as in the AXAF mission, Lincoln Laboratory is participating with CSR in the design and fabrication of the CCD sensors. Final delivery of the flight instruments took place this spring. Members of the X-ray astronomy group at MIT are joining the ISAS team in planning for the first phase of X-ray observations through most of 1993.

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 December 1994. The HETE consortium includes scientists from Los Alamos National Laboratory, the University of Chicago, CNES/CESR (Toulouse, France), the University of California (Berkeley and Santa Cruz), and RIKEN (Japan). HETE will search for bright transient emissions from astronomical objects over a very broad energy interval extending from the ultraviolet to gamma rays. The primary objective of HETE is to reveal the basic nature of enigmatic celestial gamma-ray bursts by determining their precise locations and broad-band spectral properties, and to probe the underlying physics of the emission which takes place under extreme values of temperature, density, and magnetic field. Recent results from the Compton Gamma Ray Observatory have intensified speculation that the bursts are extragalactic phenomena, such as the collision and coallescence of neutron stars to form a black hole. The HETE instruments will be mounted on a novel "mini-spacecraft", which will be dropped from a high altitude jet aircraft and injected into low earth-orbit using the Pegasus launch system. NASA and MIT have now signed an MOU and a contract giving MIT considerable latitude to carry out the mission.

X-ray Timing Explorer (XTE). This X-ray astronomy satellite is scheduled for launch in 1996 This mission was recently restructured to accommodate launch on an expendible launch vehicle, rather than the space shuttle. XTE will study the time variability of celestial X-ray sources at time scales ranging from tens of microseconds to years over energies of 2-100 keV. A group under Professor Bradt and Dr. Alan Levine is responsible for one of the three experiments on XTE, namely the All-Sky Monitor (ASM) that will be used to detect the appearance of new X-ray sources or changes in the intensity of existing sources. MIT is also responsible for a complex on-board data system that will accommodate the high data rates expected from the large-area detectors. The design effort is well underway.

Explosive Transient Camera (ETC). This MIT facility, co-located with the MDM Observatory on Kitt Peak (see next item), is designed to search the entire night sky for brief flashes of light suspected to be emitted concurrently with high-energy gamma-ray burst events. Fully automated operation of a test array began in May, 1987, under the supervision of Drs. Ricker and Vanderspek, including remote command and data retrieval over Internet from the MIT campus. Currently the ETC is carrying out coordinated observations of gamma-ray burst events detected by NASA's new Gamma Ray Observatory (GRO) launched in April, 1991. This activity will continue over the next 3-4 years.

THE MICHIGAN-DARTMOUTH-MIT (MDM) OBSERVATORY

The Michigan-Dartmouth-MIT Observatory, located on Kitt Peak near Tucson, Arizona, is comprised of two separate telescopes 1.3 and 2.4 m in diameter, and is operated jointly by the University of Michigan, Dartmouth College and MIT (CSR).

The 2.4 m mirror, which was refigured to improve its optical quality, was reinstalled in March 1991. The secondary mirror was refigured and returned in May 1991. The FWHM, as measured using Hartmann tests, is now 0.45" as compared to 1.2" prior to refiguring. We are consistently getting median seeing of 1.0". Efforts to control the thermal environment at the 2.4 m telescope dome have produced further improvements in the image quality. There are still residual problems with the mirror support, and the staff is installing electronic mirror position and airbag pressure monitors. The 1.3 m telescope continued to be actively used.

MIT has been developing several instruments for MDM. A modular spectrograph, funded by NSF and being built jointly with Michigan, will be completed this fall. A Wilbur 2048x2048 Loral CCD plus Leach controller, built by Professor Tonry and his student, is now operational and a second Leach controller system is under construction. Other activities underway or under consideration include an echelle spectrograph with CCD camera, active optics to improve image quality, and an infrared detector.

Observers at MDM are primarily members of Departments of Physics and EAPS. There are typically 20 proposals per year. Data for four PhD theses were obtained at MIT this past year.

A major activity involves studies of stars, nebulae, galaxies and clusters of galaxies discovered at other wavelengths. Professor Bradt, Dr. Remillard and students obtained spectroscopy and photometry of active galactic nuclei and cataclysmic variable stars identified in the HEAO-1 hard X-ray survey. Dr. Remillard obtained spectra of stellar sources identified by the ROSAT X-ray satellite in the galactic plane. Professor Lewin and student Magnier have produced a mosaic digital image of the nearby Andromeda galaxy, M31, and of M81 for use in identifying new X-ray sources identified by the ROSAT satellite. Professor Kistiakowsky is searching for optical counterparts to supernova remnants and planetary nebulae using narrow band images.

Professor Schechter and student observed a gravitational lens system and obtained the first evidence of the lensing galaxy. Professor Tonry has been using the improved 2.4m telescope to pursue his studies of surface brightness fluctuations in elliptical galaxies to measure their distances, and thereby determine the Hubble constant.

Professor Binzel (EAPS) has continued his photometric comparative study of near-Earth and small main-belt asteroids.

More details on the optical astronomy research program are given in the report of the Astrophysics Division of the Physics Department.

RESEARCH IN SPACE PLASMA PHYSICS

Interplanetary and Magnetospheric Plasmas. Professor John Belcher, Dr. Alan Lazarus and students continue to study the properties of solar wind plasma at large distances from the Sun using Voyager 2. Primary analysis of data on Neptune's magnetosphere has been completed and reported. The group is studying the interaction of the solar wind with the termination shock, thought to be at ~70 AU from the sun. It is hypothesized that the 2-3 kHz radio noise bursts received by Voyager are caused by this interaction. The group has recently assumed responsibility for the data processing activities that formerly were carried out at Goddard Space Flight Center. Analysis of the solar wind with continue as the Voyager 2 spacecraft races toward the termination shock -- predicted arrival in roughly 9 years.

The plasma instrumentation for the WIND spacecraft has now been delivered. Launch has been delayed until the summer/fall of 1993. 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 Drs. Geoffrey Chew, David Tetreault, students and visitors. 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. Studies include a theoretical explanation of ion acceleration in the ionosphere. It is proposed that non-linear "cavitons" excited by downwardly streaming electrons, accelerate the ions to energies up to tens of keV. These ions are then detected in the magnetosphere. Detailed computations of the ion distribution functions are being tested by rocket and satellite experiments.

PLANETARY STUDIES

Magellan Venus Radar Mapper Mission (MGN). This mission, designed to map the entire surface of Venus at a resolution approaching 100 m using synthetic aperture radar (SAR) techniques, arrived at Venus on August 10, 1990 and has nearly completed its third 8-month cycle of observation (a cycle corresponds to one full rotation of Venus under Magellan's orbital plane). Professor Gordon Pettengill is the Principal Investigator for the radar portion of this mission, with support from Professor Sean Solomon (EAPS) and Dr. Peter Ford. Although the SAR data reduction and image production is being carried out at NASA's Jet Propulsion Laboratory, CSR has responsibility for analyzing the ancillary altimetric and radiometric data and for presenting the results as images and digital data sets. NASA has recently released an optical disc set containing MIT processed data from the first cycle of observations. The radiometry data show regions of surprisingly low emissivity (therefore high reflectivity) located at high elevations on the surface. At present it is not possible to distinguish whether these regions are smooth and highly reflective, like ice, or are reflective because they are fluffy and effectively multilayered. Magellan is now completing its third mapping cycle, and the future of the mission is still financially uncertain.

Mars Observer Mission (MO). Professors Pettengill and Solomon are also involved in an experiment using a laser altimeter to determine the surface relief of Mars at a lateral surface resolution of 160 meters, and with a vertical accuracy of several meters. This instrument, developed at Goddard Space Flight Center, has been delivered to the spacecraft manufacturer for integration and will be placed in orbit around Mars by the MO spacecraft in the fall of 1993.

RADIO ASTRONOMY

A number of approaches have been taken to enable the placing of satellites in space that can serve as radio telescopes, synchronized with the world-wide network of telescopes on the ground. The combined array allows one to map radio sources with an angular resolution far greater than that achievable from ground arrays alone. Two missions are planned at present: RADIOASTRON, a Soviet mission, and VSOP, a Japanese mission. Both missions are proceeding, toward launches in 1995. The MIT activities lead by Professor Bernard Burke have been focused on technical support and mission planning support for these missions.

The technical means for the discovery of planets orbiting other stars and for studying the physical characteristics of such systems have advanced greatly in recent years. There are immediate approaches that can be taken that concentrate on indirect detection. Eventually, however, it should be possible to detect such exoplanets (a recommended term for planets belonging to other solar systems) by direct means. One approach, requiring long-range planning, would be to design such a system for emplacement on the moon. A study of these possibilities has been published. In the meantime, NASA has formed a science working group to lay out an orderly program for developing missions, both in the near-term and some years into the future, with Burke as chairman. Professor Burke also continues as Principal Investigator of the US team participating in the NASA project to establish a VLBI station in Earth orbit (formerly known as QUASAT), now envisaged for realization in association with Japan, or possibly the Russians, in the mid 1990's.

COSMOLOGY AND GRAVITATION RESEARCH

Gravitational Wave Research. The Laser-Interferometer Gravitational Wave Observatory (LIGO), a joint project of Caltech and MIT to develop and construct two 4km baseline gravitational wave interferometers in the continental United States to operate in concert with interferometers in Europe, continues research and development. The intent of the project is to detect gravitational waves originating from astrophysical sources. Current research has been dedicated to improving the performance of a 40 meter prototype at Caltech, demonstration of interferometric techniques applicable to the large scale system, and improvements in ground noise isolation and reduction in the influence of thermal noise. The MIT group also carries out studies on its 5 meter fixed interferometer. Plans are now being made to suspend the masses on this system as well. Sites for LIGO have now been selected by NSF; they are Washington and Louisiana. The project is directed by Professor Rochus Vogt of Caltech and the principals at MIT are Professor Rainer Weiss and Dr. David Shoemaker.

Cosmology Research. The Cosmic Background Explorer (COBE) Mission continues to take data on the anisotropy of the CBR on angular scales 7 degrees and larger at 30, 50 and 90 GHz and maps the sky in four bands between 1 and 5 microns. The COBE group recently announced a major discovery: residual anisotropies in the microwave background with amplitude ~15 microKelvin and correlation scale 10-20 degrees. These findings are consistent with inflationary scenarios for the formation of large scale structure in the universe.

The MIT balloon-borne radiometer was successfully reflown to obtain further data on the anisotropy at still smaller scales. Preliminary analysis of data from the earlier flight appear to be consistent with the COBE measurement. A second flight this spring of a new payload built in collaboration with Goddard Space Flight Center has successfully obtained data on still smaller scales to look for microwave fluctuations associated with foreground clusters of galaxies (the so-called Sunyaev-Zeldovich effect).

AEROSPACE PHYSIOLOGY AND MAN-MACHINE SYSTEMS

Prof. Laurence R. Young (A&A), assisted by Dr. Charles M. Oman (A&A), Dr. Dan Merfeld, and their colleagues in the Man-Vehicle Laboratory (MVL) have been analyzing data from their successful flight of SLS-1 (June 1991) and from an equally successful International Microgravity Lab-1 flight in January. Professor Young has moved to Johnson Space Center to begin training as a mission specialist, and Dr. Oman is directing MVL.

The MVL activity in expert systems ([PI] = "PI in a box") will now be incorporated into the reflight of the SLS-1 experiment on SLS-2. This flight is expected to take place in the summer of 1993.

THEORETICAL ASTROPHYSICS

Several faculty associated with the Center for Space Research carry out research programs in theoretical astrophysics. Topics include cosmology and the inflationary universe scenario, the large scale structure of the universe, galaxy formation, studies of cooling flows in clusters of galaxies, star formation, binary star evolution, physics of active galactic nuclei, and other topics. Details of this research are presented in the report of the Astrophysics Division of the Physics Department.

CLAUDE R. CANIZARES

Experimental Study Group

For the past twenty-four years, the Experimental Study Group (ESG) has provided a unique educational alternative to the regular curriculum for freshmen at MIT, an alternative based on the concepts of self-paced, self-motivated studies and learning in tutorials and small groups. ESG began in 1968 and is the oldest alternative freshman program at MIT. It continues to attract a great deal of interest from incoming students, primarily because its flexible structure can accommodate the educational needs of a variety of students.

STUDENT STATISTICS

ESG enrolled 62 students this year for one or more terms in its core curriculum in chemistry, biology, physics, mathematics, humanities and social sciences - 47 freshmen, 1 sophomore transfer, and 14 ESG upperclassmen. The breakdown by term of enrolled students (including non-ESG students attending ESG seminars) is as follows:

	Fall 1991	Spring 1992
Freshmen	45	37
Sophomore transfers	1	0
Upperclassmen who were in ESG	9	9
Non-ESG upperclassmen in ESG seminars	17	38
Total enrollment	72	84

Thirty-four percent of ESG's freshman class for the year were female, 23 percent were minorities, and 15 percent were international students from countries as diverse as Trinidad, Malaysia, the United Arab Emirates, and Yugoslavia.

The 51 sophomores currently registered at MIT who had been in ESG as freshmen earned a cumulative median grade point average of 4.3 this spring, as compared with a figure of 4.1 for the entire MIT sophomore class. A higher percentage of ESG students tend to major in the sciences than do their regular curriculum counterparts; this year 36 percent of our sophomores are majoring in the School of Science, as compared to 24 percent of the MIT sophomore class enrolled in the School of Science.

ADMINISTRATION

Professor Ingram, Director of ESG, and Andrea McGimsey '87, Assistant Director, oversaw the administration of the program in consultation with the ESG Advisory Committee. The committee is chaired by Professor Alan Davison of the Department of Chemistry. Members who continued from previous years include Professor Alar Toomre of Mathematics and Professor Lee Grodzins of Physics. We were pleased to have the following faculty members join the committee this year: Professor Robert Birgeneau, Dean of Science, Professor Philip Khoury, Dean of Humanities and Social Sciences, and Professor Jack Kerrebrock of Aeronautics and Astronautics. We would like to thank Professor Arthur Kaledin of History and Professor Gene Brown, former Dean of Science, for serving on the committee last year.

Along with their administrative roles at ESG, both Professor Ingram and Ms. McGimsey taught in ESG. Holly Sweet, Associate Director of ESG, has been on sabbatical this past year and will be returning to ESG in the fall; this year she continued to teach at MIT and served as a consultant to the program.

STAFF AND FACULTY

We were very fortunate this year to have Professor Emeritus Robert Hulsizer join the physics teaching staff of ESG. He intends to continue teaching at ESG, as both he and his students expressed much enjoyment in working together this year. In addition to Professor Hulsizer, the physics staff included Professor Emeritus Robert Halfman, Dr. Peter Dourmashkin, Craig Watkins, David Custer '82 and Sen-Ben Liao '90. The mathematics staff was headed by Craig Watkins and included post-doctorates Yifan Zhou and Arlie Petters and graduate students Dan Arnon, Eitan Bachmat, Frank D'Ippilito, Carl Dou, Michael Hawrylycz, and Zongyi Li. The chemistry staff was headed by graduate student Todd Anderson and included Michelle Bush '91.

Our chemistry, physics, and mathematics staff were assisted by 21 undergraduate tutors (most of whom had been in ESG as freshmen). These tutors shouldered a good portion of ESG's teaching load, yet managed to maintain a 4.8 cumulative median grade point average. We consider our undergraduate tutors to be one of ESG's finest assets and indispensable to the successful operation of our program.

ESG also offered several HASS-D and HASS classes to its students. Dr. Dourmashkin developed and taught a HASS-D course SP2H2 Origins of Experimental Science in the Sixteenth Century in which students investigated how contributions from the arts, anatomy, technology and mechanics helped to generate a new order of thought underlying observational science. Eric Fernald, graduate student in Political Science, taught two courses in political science, and Mr. Custer taught both expository and creative writing.

For several years ESG has been offering undergraduate and freshman advisor seminars, both for ESG students and for students in the regular curriculum. This year we offered a variety of seminars in the history of science, sociology, literature, and theater which attracted a total of sixty-two students.

SEM 051 Sex Roles and Relationships was sponsored by ESG for the seventh year in a row; Ms. Sweet and Dr. Samuel Osherson (author of *Wrestling with Love* and *Finding Our Fathers*) co-taught the seminar both semesters. During IAP Mr. Anderson and Ms. McGimsey offered a new literature seminar 21.198 Men and Women 1890's-1991: Kate Chopin to Clarence Thomas. In the spring semester Ms. McGimsey developed and taught the seminar 21S70 Theater and the Audience; the seminar was supported by a grant from the Council for the Arts, as well as funds from the Dean of Science, the Undergraduate Academic Affairs Office, and the Music and Theater Arts Section. For the third year Professor Ingram taught SEM073 The Making of a Scientist.

ESG continues to provide a home for students and staff at MIT who are interested in a more individualized and experimental approach to education. In keeping with the spirit of ESG's history of educational innovation, we have been working on four new initiatives for the coming academic year: 1) 8.01 and 8.02 Physics taught through the building of robots; 2) a twenty-four unit course combining the material of 7.01 General Biology and 3.091 Introduction to Solid-State Chemistry; 3) a new seminar on Introduction to Electronics; and 4) the acquisition of access technology for students with disabilities. We applaud the efforts of all of our community members who have contributed in their own ways this year in maintaining ESG as a valuable Institute resource for curricular and social innovation.

VERNON M. INGRAM
ANDREA C. MCGIMSEY

George Russell Harrison Spectroscopy Laboratory

The George Russell Harrison Spectroscopy Laboratory is engaged in research in the field of modern optics and spectroscopy for the purpose of furthering fundamental knowledge of atoms and molecules and pursuing advanced engineering and biomedical applications. Techniques include the use of lasers and modern optics, microcomputers and other data acquisition systems. The Laboratory is directed by Professor Michael S. Feld of the Department of Physics. Professor Jeffrey I. Steinfeld of the Department of Chemistry and Dr. Ramachandra R. Dasari, Principal Research Scientist in the Laboratory, are Assistant Directors. Professors Michael S. Feld, Robert W. Field, Keith A. Nelson, Stephen J. Lippard, Jeffrey I. Steinfeld, Toyoichi Tanaka, Mark S. Wrighton, and Drs. Ramachandra R. Dasari and Richard P. Rava are core investigators of the Laboratory.

An Interdepartmental Laboratory, the Spectroscopy Laboratory encourages participation and collaboration among researchers in various disciplines of science and engineering. Research contributors this past year were from several MIT departments, including Chemistry, Physics, Biology, Electrical Engineering and Computer Science, Mechanical Engineering and Applied Biological Sciences. There were also numerous collaborations with outside academic institutions, many of an interdisciplinary nature, as well as with government, industrial and medical organizations.

This past year was one of continued growth. Several new facilities were set up. A new cw Ti: Sapphire laser pumped by an Ar ion laser was set up in the atomic physics laboratory. A Satori femtosecond dye laser capable of producing ~150 fs pulses was installed as part of the development of the picosecond / femtosecond laboratory. A regenerative amplifier along with four stage dye amplifier chain produces 300 fs pulses with energy ~25μJ at 640 nm. Near IR Raman spectroscopy facility is augmented with a CCD detector to enhance sensitivity and to reduce data acquisition time for clinical applications.

Prof. Feld was presented the Thompson Award of Spectrochimica. Acta B, at the 47th International Symposium on Molecular Spectroscopy at the Ohio State University, Columbus. Dr. David M. Sammeth and Paul Falkos were appointed for the staff of the Laboratory. Dr. Richard Rava and Gary Hayes left to take up positions elsewhere.

The MIT Laser Biomedical Research Center (LBRC) is now in its seventh 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 three categories: Optical histochemistry; molecular mechanisms of tissue ablation; and biophysics and biochemistry of biopolymers. In addition to core research, collaborative and outside research projects are conducted at the Center. Resources of the Center are provided free of charge, on a time-shared basis, to medical researchers who wish to pursue research in this important new field.

The National Science Foundation continues to support the MIT laser research facility which conducts core research programs in the physical sciences. New laboratories and new equipment have been added to facilitate the programs of the NIH, NSF and industry grants. Currently, there are over 40 major laser systems. Equipment and facilities include continuous wave and pulsed dye lasers pumped by ion lasers, excimer lasers and Nd:YAG lasers; a pulsed Ti: Sapphire laser pumped by Nd:YAG laser; a tunable laser facility which provides intense pulses of light continuously tunable over the wavelength range 216-4500 nm; a picosecond/femtosecond dye laser facility along with a single photon counting detection system; an infrared diode laser spectrometer tunable in the 3-30μm wavelength region; UV and visible resonance Raman facilities; stopped flow kinetic apparatus; nanosecond transient absorption system; Near IR Raman spectrometer with CCD detector; FT-IR and FT-Raman spectrometer; equipment for performing spectrally resolved fluorescence microscopy and fluorescence lifetime studies; and computer interfaced absorption and fluorescence spectrophotometers. Auxiliary equipment includes transient digitizers, fluorescence microscopes and several optical multichannel spectral detectors.

RESEARCH HIGHLIGHTS

Professor Steinfeld conducted infrared double-resonance spectroscopic measurements on high overtone levels of small gas-phase molecules such as methane and ammonia. The information on energy levels, line intensities, linewidths, and collisional relaxation in these levels, gained from such experiments, is needed for interpretation of spectroscopic remote-sensing measurements of objects in the Solar System such as Jupiter, Saturn, and Titan, as well as monitoring of "greenhouse gases" in the Earth's own atmosphere.

The experiments have also studied the $v_2 = 1$ and $v_2 = 2$ states of ammonia, resulting in clarification of many outstanding questions relating to rotational- and symmetry-state changing collisions in this molecule. Photoacoustic spectra have been recorded in the 8800 cm^{-1} ($3\nu_3$) and 4100 cm^{-1} [$3\ (\nu_2,\nu_4)$] regions of methane. Using a tunable semiconductor diode laser as a probe, double resonance signals have been obtained for selected lines in the $3\nu_3$ band, permitting initial assignments to be made for these features. Additional work has been carried out on asymmetrically duterated methane species (CHD_3), in order to assess the influence of molecular symmetry on rotational inelasticity. The experiments are being carried out in collaboration with Dr. Stephen Coy, Dr. Bernd Abel, and Dr. Alex Golger.

Professors Robert W. Field and Robert J. Silbey and Dr. David M. Jonas reported the first measurement of the electric dipole moment of the $\tilde{A}^1A''$ state of HCN. The a-component of the dipole moment was determined by the Stark splitting of the Q(1) transition in a novel Stark cell capable of sustaining high electric fields (41kV/cm) at pressures of 50 mTorr. The observed value of the dipole moment μ_a=0.99(10) D is in agreement with simple molecular orbital expectations.

High resolution fluorescence spectra of the $\tilde{A} \leftarrow \tilde{X}$, $2_0^1\ K_0^1$ band were recorded with VUV radiation produced by 4-wave sum mixing. Surprisingly, the asymmetry doubling of the upper state does not extrapolate to zero at J=0. The most plausible explanation for this anomalous asymmetry doubling is a spin-orbit perturbation by a nearly degenerate level of the $1^3A'$ state.

These investigators have also studied the ground state vibrational dynamics of acetylene. Using dispersed fluorescence and stimulated emission pumping techniques (SEP) additional progressions were recorded. They were able to assign these progressions as being due to a strong but previously undetected Darling-Dennison resonance. In SEP the ability to select single rotation-vibration levels in the intermediate state greatly simplifies the spectra allowing complicated dynamics to be resolved. These experiments also provided the first evidence of the anti-symmetric stretch in the SEP spectrum, and opens up a key pathway for intramolecular vibrational relaxation (IVR). This IVR pathway may explain the dynamics of the vinylidene-acetylene isomerization reaction.

In other SEP experiments in acetylene, nominally forbidden rotational transitions ($|\Delta K| \equiv |K' - \ell''| \leq 3$) were observed in the 7000 cm^{-1} region of the $\tilde{X}$ state via rotational-ℓ-resonance in the $\tilde{X}$ state and axis-switching. The observed range of the intensities of the strongest to the weakest detectable SEP transitions in this region is probably greater than 1000. This unexpected dynamic range may be important for the reinterpretation of previous SEP spectra. For instance, in the case of acetylene, this unexpectedly large sensitivity range coupled with the newly discovered strong vibrational resonances may now reconcile the difference between the larger observed density of states at 15,000 cm^{-1} and the density of states calculated from a symmetry sorted direct anharmonic count.

Using ultraviolet double resonance technique, Professors Field and Silbey and Dr. James K. Lundberg studied the spectra of C_2H_2 and C_2D_2 in the 7400-7800 cm^{-1} region. The vibrational progressions observed in the one-photon VUV spectrum, and assigned to the $\tilde{E}$ state, also appeared in the two-photon spectrum. Although the $\tilde{E}$ state is strongly predissociated, with the individual rotational levels surviving for only ~1 ps the double resonance technique permitted observation of rotationally resolved spectra of this state, which in the VUV spectra can only be described as diffuse. A group theoretical analysis of this data indicated that the $\tilde{E}$ electronic state has a *nonplanar* near *cis* -bent structure, and a ^1A electronic symmetry. This is the first experimental observation of a *nonplanar* acetylene structure. Because the fluorescence-depletion detected double resonance technique can provide rotationally resolved spectra of strongly predissociated vibronic states, this is a very powerful method capable both of direct probing of these short lived states and selective preparation of neutral fragments for further spectroscopic and reactive experiments.

Professor Field and Dr. Ernest Friedman-Hill have studied weak molecular transitions by placing a sputter source, capable of generating a variety of metal containing hydride, oxide, halide and nitride molecules, inside the cavity of a CW, standing wave laser. Definitive information about the electronic structure of the NiH, PtN and NiO molecules has been obtained. These molecules provide crucial tests of the "Atomic-Ion-in-Molecule" electronic structure model being developed.

Prof. Keith A. Nelson of the Department of Chemistry and his students have constructed an amplified femtosecond laser system capable of measuring optical processes occurring on a two hundred femtosecond time scale. The laser pulse is amplified to high energies, allowing nonlinear optical properties of various materials to be measured. During the course of the year, ultrafast experiments were carried out on special nonlinear optical glasses manufactured by Corning Glass works to be used in the fiber optic industry. Electronic and nuclear processes that determine the ultimate performance of these materials were successfully measured. Many ambitious projects have been planned for this new system. Low frequency Raman processes in large proteins and the charge transfer dynamics of photosynthetic systems will be studied using the femtosecond pulses.

Professor Stephen J. Lippard of the Department of Chemistry and Dr. Axel Masschelein have pursued their studies of the reaction of dioxygen with dinuclear iron complexes by stopped-flow kinetics and Raman spectroscopic methods and, have investigated the mechanism of the hydorxylase enzyme of methane monooxygenase. In collaboration with Dr. John D. Protasiewicz, the mechanism of the reductive coupling of two carbon monoxide ligands on transition metal centers has been studied; with Dr. Sofi K. C. Elmroth, DNA promoted reactions have been studied; and with Dr. Tong Ren, thermochromic equilibria of platinum complexes have been elucidated.

During the past year Professor Mark S. Wrighton of the Department of Chemistry and his collaborators have been involved in studies of the excited state electron transfer dynamics involving molecules in solution and molecules anchored to surfaces. The experimental studies require use of transient Raman and absorption spectroscopies and measurements of luminescence lifetimes. The overall aim of the studies is to understand the factors controlling rates of forward and reverse electron transfer in assemblies of molecules constructed to duplicate the early events in natural photosynthesis. One project, conducted with Dr. Charles Christ, has established that electrode-confined molecular assemblies can be used as the elements needed to absorb light and separate charge to sustain the photooxidation of so-called sacrificial reagents such as organic amines. In another project, semiconductor clusters have been capped with ferrocenyl ligands capable of photoinduced electron transfer, and quenching of excited state emission has been demonstrated.

Professor Steven R. Tannenbaum and Dr. Paul L. Skipper of the Department of Chemistry/Division of Toxicology and Drs. Ramachandra R. Dasari, Richard P. Rava, and Kuldip Singh of the Harrison Spectroscopy Laboratory have continued their studies of the fluorescence of protein and DNA adducts of chemical carcinogens. Laser-induced fluorescence line narrowing spectroscopy was used to aid in elucidation of the structures of cyclopenta[cd]-pyrene bound to mouse hemoglobin *in vivo* and of benzo [a]pyrene bound to core histones from cells in culture. Laser-induced fluorescence spectroscopic methods were developed for quantitative analysis of 7,8,9,10-tetrahydroxy-7,8,9,10-tetrahydroxybenzo [a]pyrene, which is the product of hemoglobin of hemoglobin adduct hydrolysis.

Professor Alexander Rich of the Biology Department and his collaborators have measured Z-DNA in the c-myc oncogene by crosslinking the antibodies to DNA using a Nd-YAG laser at 266 nm. These experiments use Biotin labeled monoclonal antibodies against Z-DNA which are diffused into human U937 cells to measure Z-DNA in the nuclei. The crosslinked DNA is isolated by restriction digestion. Three restriction fragments of the c-myc gene are shown to form Z-DNA when the cells is transcribing c-myc. However, when U937 cells start to differentiate and transcription of the c-myc gene is down regulated, the Z-DNA content goes to undetectable levels within 30 to 120 minutes. Dr. Alan Herbert has developed a technique to map Z-DNA binding proteins on supercoiled plasmids in vitro. This method is used in the purification of Z-DNA binding proteins and mapping of the DNA-binding sites.

Professor Moungi Bawendi of the Chemistry Department studied the fluorescence properties of semiconductor nanocrystallites. The SPEX Fluorolog has been used for routine cw characterization of samples of CdSe and CdS nanocrystallites. The picosecond apparatus for time-correlated photon counting was used to study the carrier trapping process in the crystallites as a function of particle size and temperature (1.6 to 50 K).

Professor H. Gobind Khorana of the Chemistry and Biology Department and his colleagues, Dr. David L. Farrens and Dr. Duncan A. Greenhalgh studied the biological photoreceptors bacteriorhodopsin and rhodopsin. The goal of the studies is to develop a dynamic, molecular understanding of these light-triggered switches. Using site-specific mutagenesis, regions of the protein are changed and the effect was studied by transient absorption spectroscopy. Seven different genetically engineered bacteriorhodopsin proteins have now been characterized using the above technique. Another project has begun to perform similar of the visual pigment rhodopsin. These first ever measurements include studies of engineered rhodopsin samples constructed with the same genetic alterations found in night blind patients.

Professor Toyoichi Tanaka, Dr. Masahiko Annaka of the Department of Physics, and Dr. Richard Rava of Spectroscopy Laboratory worked on spectroscopy of multiple phases of gels. Synthetic polymer gels are known to exist in tow phases, swollen and collapsed. Volume transition occurs between the phases either continuously or discontinuously. More than two phases are found in gels consisting of copolymers of randomly distributed positively and negatively charged groups. They are characterized by distinct degrees of swelling; the gel can take one of a set of swelling values, but none of the intermediate values. The number of phases depends on the composition of positively and negatively charged monomers, and decreases from a maximum of seven at a particular composition to one at pure cationic or anionic gel compositions. In these gels, polymer segments interact with each other through attractive or repulsive electrostatic interactions and through hydrogen bonding. The combination of these forces appears to result in multiple phases. The finding indicates that the equation of state for polymer systems, in which only a single variable, χ-parameter, is used to describe the polymer-polymer interaction, needs a fundamental modification. It will also provide the physical basis with which to understand the structures and specific functions of polymers only known to biopolymers. At this moment, the nature of the multiple phases, in particular, their microscopic structures are unknown. Spectroscopic studies of the gels at different phases using infrared, Raman scattering, ^{13}CNMR, neutron scattering, and dynamic light scattering spectroscopy are underway.

Professor David E. Pritchard of the Department of Physics and his colleagues, Dr. Alex Martin, Dr. Wolfgang Ketterle have developed an intense source of slow atoms. Fluxes of up to 10^{12} sodium atoms were obtained using a special magnetic field configuration to compensate for the changing Doppler shift during the slowing process. In addition, the slow atom beam could be collimated and deflected. This atom source is now being used to load an atom trap and will be used to study high density samples of ultracold atoms.

The spectroscopy of the diamagnetic Rydberg atom carried out under the direction of Prof. Daniel Kleppner of the Department of Physics is playing a central role in quantum chaos and the physics of non-separable systems. In previous years, the experimental results have helped to stimulate theoretical advances. However, the productivity of the research was limited by the difficulties associated with the antique superconducting magnet. For example, the stray electric field was a limiting factor. During the past year, work has begun on a new apparatus which will greatly reduce the stray electric field. In addition, an electric field can be applied as an additional probe of the system. Thus one can also study diamagnetic Rydberg atom in electric field in detail. The data taking on the new apparatus is just under way.

Professor Feld and Dr. Dasari and their colleagues have continued experiments to study the interaction of a single atom in an open optical resonator. As part of this investigation Na atoms were slowed and cooled to velocities ~40 m/s and high atomic densities ($> 10^7$ cm^{-3}) using an intense standing wave laser beam with a counter propagating component. A careful and detailed analysis was made using a semi-classical model that we have developed, which suggested the use of a super-cavity resonator for further studies in coupled atom-cavity systems. We plan to measure the atom-cavity coupling strength and study the associated photon statistics. Another experiment is under way to observe novel effects attributed to the onset of stimulated emission in a system of a few atoms coupled to a super cavity mode. Atomic beam apparatus has been fabricated and tested. This work is part of a long-term program to study superradiance and other coherent radiative processes in an optical resonator.

Professor Ali Javan of the Department of Physics and Dr. Michael Otteson have continued experiments to improve measurements of the ν_8 vibrational band of sulfuryl fluoride. These measurements were made with a $^{13}CO_2$ laser and a Pb-salt diode laser such that the accuracy of the J to J+1 transitions in the ν_8 vibrational band of this molecule will increase by a factor of 50 to 100. Metal-oxide-superconductor junctions have been developed and tested in the laboratory. Very large nonlinear responses have been measured and these measurements have been used in the modeling of the physical properties and responses of these junctions. Experiments are underway to measure the higher order nonlinear responses of these junctions at infrared and optical frequencies.

Professor Feld and Dr. Rava and their colleagues continued in biomedical research using laser induced fluorescence to diagnose disease in human tissue. A novel method has been developed to extract intrinsic fluorescence information form the laser induced fluorescence spectra taken from bulk samples of tissue. The method is based on a novel photon migration model which gives simple and accurate analytical results for both fluorescence and diffuse reflectance. Experiments in aortic media confirm the validity of the model.

Prof. Feld and Dr. Rava are also engaged in biomedical research using vibrational spectroscopy to diagnose disease in human tissue. Especially near IR excited Raman scattering technique is used to derive histochemical information from pathologic tissues. Recent effort includes development of rapid Raman spectroscopy using CCD detector and spectrograph capable of diagnosing disease *in vivo* in real time.

Professor Feld, Drs. Dasari, Rava and Dr. Ramasamy Manoharan, of the Spectroscopy Laboratory have studied spectral properties of individual constituents of human artery using FT-IR and FT-Raman techniques. These tissue components include collagen, elastin, cholesterol, cholesterol esters, phospholipids, triglycerides, glycosaminoglycans and calcium hydroxy apatite important in the pathogenesis of atherosclerosis. The spectral data have been used to model the spectra of different pathologic human arterial tissue, in order to derive quantitative information such as relative concentration of individual components in pathologic tissues.

Professor Feld, Drs. Dasari, Rava and Manoharan, have been using micro spectroscopic and micro photographic techniques to spectroscopically characterize structures of few microns in size in human tissues. Fluorescence and IR absorption spectroscopic measurements from an extremely small sample volume ($10 \times 10 \times 5\ \mu m^3$) is being carried out to understand the bulk spectroscopic signal from human aorta, colon and bladder.

Professor Feld, Drs. Irving Itzkan, Sargent Janes and Lev Perelmen of the Spectroscopy Laboratory are developing a new approach to the theoretical understanding of the mechanism of the laser ablation of biological tissue by short pulses. They have termed the mechanism Inertial confinement ablation because, during the laser pulse, the tissue does not have time to move, thereby generating intense pressures rather than high temperatures. It is the high pressures which then causes the tissue to disassemble and ablate, rather than thermally vaporize.

Professor Feld, Dr. Itzkan and Dr. Janes are exploring experimentally the mechanism of pulsed laser ablation and have conducted a series of experiments to establish the parameters of ablation by multiple pulses. They are now setting up to monitor the motion of the tissue with an interferometric technique. The understanding obtained from this experimental program coupled with the theoretical program described in the previous paragraph will be important in designing lasers for various microsurgical applications.

Professor Feld, and Drs. Itzkan and Janes in association with Dr. John Kramer of the Department of Cardiology of Cleveland Clinic Foundation have continued development of a spectroscopically guided laser angiosurgery system for treating atherosclerosis. In a clinical trial, sixteen patients undergoing bypass surgery were treated with the new system. The data acquired and the experience gained has been used to improve the performance of the system.

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. These activities include the programs at the MIT Center for Theoretical Physics and at the Bates Linear Accelerator Center. LNS support includes personnel, purchasing, and accounting support, as well as a central computing facility, machine shops, and an electronics design and development facility.

Through the Center for Theoretical Physics, LNS supports forefront research in theoretical nuclear and particle physics on a wide variety of topics and approaches. The primary LNS experimental programs are in the following areas. The largest local effort is in medium energy nuclear physics, at the Bates Linear Accelerator Center in Middleton, Massachusetts. Additional medium energy experiments are performed at the Los Alamos Meson Physics Facility, at the Paul Scherrer Institute (Zurich), at the Stanford Linear Accelerator Center, at the Deutsches Electronen Sychrotron (Hamburg), and at the Continuous Electron Beam Accelerator Facility. A major effort in relativistic heavy ion physics is led by an LNS group at the Brookhaven National Laboratory. In high energy physics there are major projects in the US at the Fermi National Accelerator Laboratory and at the Stanford Linear Accelerator Center. High energy experiments are also performed abroad at the European Laboratory for Particle Physics (CERN), at the Gran Sasso Laboratory (Italy), and at the Beijing Electron Positron Collider (China).

EXPERIMENTAL HIGH ENERGY PHYSICS

Electromagnetic Interactions Group (EMI)

Following the six year construction and installation program of the L3 experiment at the LEP accelerator (Large Electron Position Collider) at CERN in Geneva, Switzerland, the Electromagnetic Interaction Group (EMI) led by Professor Samuel C. C. Ting has been taking data since the machine first became operational in the summer of 1989. To date 43 scientific papers from L3 have been published including the first publication from LEP. L3 is the largest of the four LEP detectors and is distinct from the other detectors in its design and physics objectives. L3 is an ultra precise detector built with state of the art technology to study photons, muons and electrons with unprecedented accuracy. Collaborating with the MIT/LNS/EMI group on L3 is an international consortium of 510 physicists from 44 institutes and 13 different countries. It represents the first large scale high energy physics experiment in which scientists from the United States, the Soviet Union, China, and India, work together with the strong support of their respective governments. As in the past twenty-five years, the EMI group continues to bear the leading responsibility for the design, construction, installation, execution, and data analyses of all its experiments.

The LEP machine has been operating at a luminosity of $2X10^{31}$ $cm^{-2}sec^{-1}$. To date L3 has collected and analyzed more than 500k Z^o particles (the carrier of the electroweak force) and with this data sample has been able to carry out many indepth studies, among which are the following:

-We have measured the mass and width of the Z^o and were the first group to directly measure the branching ratio of the Z^o into electron and muon pairs. We have found:

The mass of Z:	$M_Z = 91.184 \pm 0.021$ GeV, and
The total width of Z:	$\Gamma_Z = 2.502 \pm 0.010 \pm 0.005$ GeV
The hadron width of Z:	$\Gamma_{had} = 1.742 \pm 0.013$ GeV.

-In the framework of the Standard Model, our results show that there are only three kinds of light neutrinos in the universe (3.07 ± 0.07).

-We have set limits on the mass of the Top quark ($M_t = 186 \ ^{+33}_{-42} \pm 14$ GeV).

-In the search for new particles, we have set limits on the mass of the charged Higgs and neutral Higgs boson ($M_{H^0} > 52.0$ GeV and $M_{H^\pm} > 44$ GeV at 95% c.l.) as well as Supersymmetric particles: scalar muons, scalar electrons, winos, and scalar leptoquarks as well as New Charged and Neutral leptons: excited electrons, muons, taus and neutrinos. (In all cases, a lower limit > 41 GeV at 95% c.l. has been obtained).

-We have determined that electrons, muons and taus all have a radius smaller than 10^{-17} inches.

-In the physics of heavy quarks, $B^0 - \bar{B}^0$ mixing and b quark asymmetries have been studied. L3 has uniquely observed the reaction $Z^0 \rightarrow B\ \bar{B}$ in which B changes to $\bar{B}$ with a probability of X_B. The signature of this phenomenon is the observation of two same sign opposite-side high-p⊥ leptons. We have obtained

$$X_B = 0.121 \pm 0.017 \pm 0.006$$

-The strong coupling constant α_s has been measured ($\alpha_s = 0.124 \pm 0.006$). We have determined that all quarks have a radius smaller than 10^{-17} inches.

-We have made the most precise measurements to date on the neutral current vector g_V and axial vector g_A coupling constants, and we have found:

$$\bar{g}_V = -0.043 \pm 0.007$$

and

$$\bar{g}_A = -0.4993 \pm 0.0016.$$

L3 plans to continue the search for new particles and physics phenomena on the frontier of physics research. LEP is planning to double its luminosity in 1992 yielding 10^6 Z^0's for L3 to analyze in 1992. The luminosity will continue to increase and by 1995 LEP will cross the W^+ W^- production threshold (LEP200). It is at these highest LEP luminosities that the unique advantages of the L3 detector in its design, precision performance, and physics potential will be fulfilled.

Collider Detector Facility (CDF) Group

The group is participating in the Collider Detector Facility (CDF) experiment at the Fermi National Accelerator Laboratory (FNAL), currently the highest-energy accelerator in the world. The CDF experiment is a collaboration of 30 institutions from the U.S., Japan and Italy, studying proton-antiproton ($p\bar{p}$) collisions at a center-of-mass energy of 1.8 TeV. Briefly, the aims of the CDF physics program are:

1. By far the most important objective is the discovery of the top quark. Previous work with the UA1 experiment at CERN has put a limit on the mass of the top quark of $M_{top} > 60$ GeV. More recent results by CDF, based on 4.5 pb^{-1}, have constrained $M_{top} > 91$ GeV. The latest results from the LEP accelerator at CERN, when combined with the precise measurement of the mass of the W boson, again from CDF, seem to indicate that the top mass must lie somewhere between 100 and 200 GeV, for (a) the Standard model to be correct and (b) for all the results from different experiments to be in agreement with each other. Beginning in May 1992, the CDF experiment started a new data-taking period, in order to accumulate another 100 pb^{-1}. With this increase in statistics, CDF should be sensitive to top quark masses up to 170 GeV.

2. Study of the second-heaviest quark, the b-quark, and its mesons. The cross-section for b-production in $p\bar{p}$ collisions is very large. CDF has thus managed to study not only the traditional semi-leptonic decays of the b-quark, but also exclusive decay modes containing a J/ψ. Up to now, the study of heavy-quark mesons has been monopolized by electron-positron colliders. With the expected increase in statistics from the coming runs, and the use of a recently installed silicon vertex detector, CDF should be able to discover baryons containing the b quark, the remaining b mesons, and also measure b-meson mixing to a greater precision.

3. The study of the W and Z intermediate vector bosons, discovered in a previous experiment, UA1 at CERN, in which MIT participated, is a continuing endeavor for the CDF experiment. An extremely important measurement is that of the mass of the W boson. If the top is discovered, then this mass measurement will give a prediction for the mass of the Higgs boson. Until the LEP accelerator is upgraded in energy, the FNAL collider will be unique in that it is the only accelerator capable of producing W bosons.

4. The study of high-P_t (transverse momentum) jets has so far delivered very stringent limits on the energy scale for compositeness (i.e. quark substructure) hypotheses. Since the FNAL collider will be the highest-energy machine in the world until either the LHC or SSC accelerators are built, it is the ideal place to search for any compositeness signals and, if none are found, to increase the limit on the energy scale for compositeness.

5. The above list is by no means exhaustive. There is a host of other subjects (supersymmetry, boson-boson interactions, magnetic moments) that can be studied. The above represent only the most important "short-term" goals for the CDF physics program.

The Accelerator Physics Collaboration

The Accelerator Physics Collaboration (APC) group is conducting experimental research at Gran Sasso (GSL) in Italy, at Brookhaven National Laboratory, and at the SSC Laboratory in Texas.

The experiment in GSL, which is the world's largest underground laboratory, will study particle physics and astrophysics problems. The particle physics problems are related to the possibility of a new type of particle being emitted from Cygnus X-3. These studies could confirm emission of such particles and provide information on the mechanisms involved and the properties of the source. This experiment can also search for neutrino oscillations. The Group will also study the production of solar neutrinos and will measure the yearly rate of collapsing stars in the universe. Another objective is the search for point sources in the universe emitting high energy neutrinos.

The Group has joined a Brookhaven National Laboratory experiment to study the creation of strangelets, which are particles that contain more than three quarks with a large number of the quarks having strange flavor. This experiment will put strong constraints on the parameters involved in QCD theory.

The group has joined the GEM Collaboration at the SSC Laboratory. We have the responsibility for the first level muon trigger using Resistive Plate Counters.

The Counter Spark Chamber Group

The Counter Spark Chamber group is continuing the development and utilization of the Stanford Large Detector (SLD) at the Stanford Linear Accelerator Center. The hardware contribution of the CSC Group was the construction of the Warm Iron Calorimeter and Muon Detector, which is now complete. The first data with a polarized electron beam have been taken. 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 CSCGroup has undertaken three new initiatives directed toward the longer term future, they are:

1. Development of a detector for the relativistic heavy ion collider (RHIC) which will be built at BNL by the middle 90's. A proposal has been submitted in collaboration with the LNS heavy ion group and is awaiting action by BNL.

2. Participation in the preparation of proposal for a major detector for Superconducting Super Collider. The group is active and will take a major role in the design and development of the so-called "GEM detector" for the SSC. This detector is planned to have superior lepton detection capability. In this connection the group has undertaken muon detector research and development.

3. The group is participating in the CDF proton-antiproton collider experiment at FNAL in collaboration with other LNS scientists.

Lepton Quark Studies (LQS)

The LQS group is collaborating on the SLD experiment on the Stanford Linear Collider (SLC) at the Stanford Linear Accelerator Center (SLAC). The group is presently participating in data runs with a polarized electron beam. This polarized electron beam will enable the study of the production of polarized Z-Bosons with left- and right-handed polarized electrons, allowing tests of the present gauge theory with unprecedented precision. In addition to this novel experiment, the group is a member of a U.S. Chinese collaboration whose aim is to exploit high statistics studies of e^+e^- interactions in the 3 to 5 GeV energy region with the Beijing Spectrometer situated at the Beijing Electron Positron Collider (BEPC) at the Institute for High Energy Physics (IHEP) in Beijing. This effort is a follow-up of very fruitful experiments carried out at SPEAR, SLAC's former storage ring collider facility, during 1982-89. This collaboration has just completed a measurement of the Tau-Lepton mass, finding it to be lower than the present world's average by two standard deviations and with an order of magnitude better precision. The value of the Tau-Lepton mass is important in understanding a small discrepancy when relating it to the decay branching ratio and lifetime, within the framework of the present standard gauge model.

The group is continuing its effort in a U.S. collaboration to participate in a possible future $e^+ e^-$ international facility operating in the SPEAR energy region known as the Tau-Charm Factory. This facility is envisioned to provide event rates 100 times and 1000 times more than BEPC and SPEAR, respectively, and to be equipped with a high precision spectrometer, allowing for continued studies of charmed mesons, charmonium states and properties of the Tau-Lepton.

EXPERIMENTAL NUCLEAR PHYSICS

Relativistic Heavy-Ion Physics (HI)

The Heavy-ion Group is a large part of the E802 collaboration, which has constructed a multi-particle spectrometer that can measure the reaction products produced in collisions induced by the 235 GeV oxygen, 412 GeV silicon, and 2.3 TeV gold beams that have recently become available at Brookhaven National Laboratory Tandem/AGS accelerator facility (unique in the U. S.). Using these beams, collisions with heavy target nuclei, from aluminum to gold, offer far higher matter/energy densities than heretofore studied, approximating conditions that may have occurred during the initial expansion of the universe. In each central collision hundreds of particles are produced. Analysis of the produced particle multiplicity and transverse energy flow, as a function of a target nuclear size, indicates that the projectiles, even at this very high energy, are indeed stopping

during central collisions with the largest nuclei, producing energy densities several-fold higher than in normal nuclear matter. Analysis of the spectrometer data has yielded the provocative result that the production of positive strange mesons (K^+)relative to normal π^+ mesons is threefold enhanced compared to proton induced reactions. We are just now analyzing data obtained from the Spring 1991 and 1992 runs that utilized a newly installed "smart" trigger. By performing particle identification within 10 μsec this allows on-line event selection, thereby increasing our data sample for K^+ by over a factor of 10. The tracking detector system is being upgraded in order to exploit the much heavier and energetic gold beams that have just become available, allowing one to reach even higher matter/energy densities. Furthermore, the MIT group has received a favorable response to a Letter of Intent, with Prof. Wit Busza as spokesman, for the PHOBOS detector for the Relativistic Heavy-Ion Collider (RHIC), which is now under construction at Brookhaven. This machine will have almost 40 TeV center-of-mass energy for gold-gold collisions beginning in 1997. The detector consists of two spectrometer arms of 10 planes of Si detectors located in pairs of superconducting coils. The readout electronics consist of custom-designed integrated circuits being developed at MIT-LNS. The whole apparatus is very compact, about 1m in scale, and will be built at a cost of $5M.

Medium Energy Nuclear Physics

About 20 MIT graduate students carried out research projects with the medium energy nuclear physics group during the past year. Experiment were performed at the MIT-Bates Linear Accelerator Center and at several other facilities.

The experiments at Bates focused mainly on electromagnetic interactions with few-nucleon systems. A measurement of the tensor polarization of the recoil deuteron in elastic electron-deuteron scattering yielded results which provide stringent tests of nuclear dynamics and quark-cluster models. An experiment on the electro-disintegration of the deuteron at threshold probed the short-range meson exchange part of the nucleon-nucleon interaction. Measurements also have been performed of the neutron charge and magnetic form factors and the neutron momentum distribution in the deuteron.

Spin-dependent electron scattering from polarized ^{3}He was observed in two experiments which used different techniques for polarizing the ^{3}He sample. The results are consistent with theoretical expectations. The polarized ^{3}He target development provides the basis for our leading role in a major experiment planned at DESY (Hamburg), which will measure proton and neutron quark distributions. It has also been used in an experiment at the Indiana University Cyclotron Facility exploiting spin observables in proton scattering. In addition to these and other planned measurements in light nuclei, a comprehensive study of quasi-elastic scattering on medium and heavy nuclei (^{40}Ca through ^{238}U) is in progress.

On the technical side, work is proceeding on the design of a large acceptance toroidal spectrometer, to be used in experiments with internal targets, and on the development of a focal-plane polarimeter for the one-hundred inch proton spectrometer.

Using the higher-energy electron beam available at SLAC, the quasielastic (e,e'p) reaction was observed in a range of nuclei from ^{1}H to ^{197}Au. At sufficiently high momentum transfer, these data may exhibit the phenomenon known as color transparency.

Several experiments on pion-induced reactions have been carried out at the Los Alamos Meson Physics Facility (LAMPF) and at the Paul Scherrer Institute (PSI), with the goal of elucidating hadronic reaction mechanisms. At LAMPF, a program to study inclusive pion scattering, single charge exchange, and double charge exchange in light nuclei (^{3}He through ^{12}C) is nearing completion. Anew, high-resolution neutral meson spectrometer is under construction to extend the studies of the ($\pi^{\pm}$, π^0) reactions. At PSI, a large acceptance (nearly 4π steradians) detector system has been constructed primarily for the purpose of

investigating pion absorption, in particular those processes leading to the emission of several nucleons. Data have been obtained on absorption in ^{3}He, ^{4}He, nitrogen, and argon, and are expected to yield information on possible new physics in the region of non-perturbative QCD.

Nuclear Interaction Group

The research of the Nuclear Interactions Group focuses on the study of electromagnetic currents in nuclei and nucleons as a means towards learning about the fundamental nature of nuclear interactions and nuclear and nucleon structure. Of particular importance are the modifications of the nucleon in the nuclear medium, the large deviation from popular mean-field description of nuclei, and the role played by two- and many-body currents. Results of experiments with the ^{12}C (e,e'p) reaction have demonstrated the inadequacy of the conventional quasi-free knockout concept for the (e,e') reaction and the importance of many body correlations. These are manifested via anomalous transverse/longitudinal cross sections and large transverse strength at very deep missing energies.

The program of (e,e'p) measurements is being extended to include the deuteron and light nuclei and to include other electromagnetic interference cross sections requiring out-of-plane measurements and polarimetry of the outgoing protons. Most of the experimental program is currently at Bates. The transverse and longitudinal response functions were measured for the deuteron,and the interference response function $R(LT)$was measured for the deuteron and ^{12}C. Out-of-plane detection of the outgoing proton and a polarized electron beam enabled for the first time a measurement of the "fifth" structure function $R'(LT)$ of both ^{12}C and the deuteron.

In addition to experimental running, the program at Bates involves collaboration on the construction of liquid deuterium targets and of the focal plane detection system for the five OOPS spectrometers used in the out-of-plane experiments. The group is helping to construct the multi-wire proportional chambers for the focal plane polarimeter used with OHIPS in a program to study polarization variables in $^{2}H(e,e'p)$ and other (e,e'p) reactions.

The group has a growing effort at the Continuous Electron Beam Accelerator Facility (CEBAF) under construction in Newport News, Virginia. The group is part of the Hall A and Hall B collaborations. In Hall A the group is developing the focal plane detection system for the two high-resolution spectrometers. The group is also responsible for target development and beam monitoring in Hall B. The approved research plans for Hall A include extension program in (e,e'p) studies with the deuteron, few-body systems and complex nuclei. In Hall B the approved program involves 4π detection to extend the multihadron program started at Bates. Future plans include studying parity violation and the strangeness content of hadrons at CEBAF and at SLAC, and an extension of multihadron studies at Mainz.

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. The simplest nucleus, the deuteron, is an important testing ground. Electron scattering, involving the measurement of very small cross sections, was used to study deuteron electrodisintegration to very high momentum transfers. It provides an important test of our understanding of short-range meson exchange and the sensitivity to the choice of form factors and nucleon-nucleon potentials. Nucleon structure is being studied in several ways. The neutron charge distribution is essentially unknown. Two complementary experiments recently carried out at Bates have provided the first direct measurements. One involved the scattering of longitudinally polarized electrons from polarized ^{3}He nuclei. The second involved a double scattering experiment which measured the polarization transfer to neutrons knocked out

quasielastically from the deuteron. Another program will study the deformation of protons. All of these efforts require major technical developments and involve novel use of polarization observables

b. Electron-proton Coincidence Experiments
Electron-proton coincidence experiments continue to be an important program at Bates. The emphasis has been on the study of this reaction process to high momentum transfers and high missing energies. A set of pioneering measurements, aimed at precision studies of the deuteron and ^{12}C, were initiated last year. These involved the use of an out-of-plane spectrometer, one of five under construction, to measure unique electromagnetic response functions. It included the first-ever measurement of the so-called fifth response function which also requires use of a polarized beam.

c. Parity
Parity non-conservation, a violation of reflection symmetry in nature, arises from the weak force. The very small difference (less than one part per million) in scattering electrons in two different polarization states from a spherical nucleus was measured at Bates. The difference was found to be consistent with that expected in the Standard Model of elementary interactions. The next such experiment will measure parity violation in electron-proton scattering and is now in an advanced development stage. The result will provide new information on the importance of strange quarks in the structure of the nucleon.

d. 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 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 is scheduled to be completed in 1992. It will be an integral part of the South Experimental Hall, using existing beam lines for experiments in the internal target mode and in the extracted beam mode.

In the internal target mode, the electrons are circulated thousands of times through a windowless gas storage 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 now make it feasible to produce gases of polarized nuclei of sufficient thickness for internal target use. Such internal target experiments, representing a significant departure from the traditional experimental configuration in electronuclear physics, will require innovative developments advancing both physics and technology. A major new detector called BLAST (Bates Large Acceptance Spectrometer Toroid) has been designed, in collaboration with scientists from eight other institutions. This large acceptance detector is matched to the luminosity and polarized target requirements of the SHR internal target facility. Peer reviews have provided strong scientific endorsement of the concept. Funding is optimistically expected to be available starting in FY94.

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 successive injection 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, measuring the nuclear pion distribution near threshold, and studying the electromagnetic structure of nucleons.

S. Kowalski, 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, nuclear many-body theory, reaction 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 in the area of lattice gauge theory, which provides a unique tool to solve, rather than model, QCD. Lattice calculations of wave functions and quark correlation functions for the pion, rho, and proton agree with experimental charge radii, demonstrate that only half the spatial extent of hadrons arise from the three-quark or quark-antiquark component of their wave function, and provide new insight into the limitations of bag and Skyrme models. A variety of analytic approaches to QCD are being explored, ranging from classical solutions to mean field and variational calculations. An effective theory of confinement has been developed in collaboration with the particle theory group which provides a new understanding of confinement in terms of the propagation of quarks in a fluctuating color field and the properties of QCD at high temperature, relevant to relativistic heavy ion experiments, have been studied.

With the addition of a new faculty member, a major research initiative has been undertaken in the study of nuclear and nucleon structure functions. In collaboration with the particle theory group, a complete classification of spin-dependent structure functions has been carried out, and new experiments have been proposed to measure many of them. In addition, independently, the first comprehensive analysis was made of all the parity-violating structure functions which can be measured at high energy where weak and electromagnetic contributions become comparable, leading to the possibility of separating the valence and sea contributions to $g1$ at HERA. A fundamental investigation relating structure functions to hadron wave functions on the light cone has also been undertaken.

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. Efforts have continued to understand the nature of periodic solutions in multi-dimensional classical systems and their implications for quantum chaos and to calculate periodic solutions for physical processes. Path integral techniques, which have previously been used by this group for a wide variety of nuclear many-body problems, have been applied to the nuclear response function. The distribution of momentum in deformed nuclei has been studied in models and in mean field theory and shown to be deformation independent. Several new approaches are being applied to nuclear many-body theory, including scattering theory and perturbation theory in time-dependent basis and application of the doorway state method to ground state properties. Developments in

reaction theory include understanding the origin of friction in the optical model, derivation of a simple approximation for highly inelastic low energy collisions, and study of interference effects in the passage of a fast particle through a nucleus.

Electromagnetic probes of nuclei have been a continuing focus of theoretical interest, both because of the unique precision of electromagnetic probes and because of important new opportunities to exploit coincidence experiments and polarization observables arising from the new Bates South Hall Ring. 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 systematic evaluation of electroweak radiative corrections. A new thrust has been investigation of the use of neutral current probes to study the strange quark content of the nucleon. Studies of the nuclear response function have addressed new approximation schemes, development of a systematic expansion for the y-scaling regime, and the study of relativistic effects.

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 and QCD. A significant new development has been the discovery of a new class of chirally-odd quark structure functions. Since these structure functions cannot be measured in chirally-conserving deep inelastic lepton scattering, new experiments have been proposed to measure them in polarized proton-proton collisions and in direct photon production. Two-baryon interactions have been studied using a hybrid bag model with external meson fields, with the goal of exploring coupled channel effects and possible exotic resonances. The possibility of producing exotic resonances in pion-nucleus scattering has also been explored. 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. Fundamental studies of hadronic interactions relevant to the physics of relativistic heavy ion collisions include calculation of J/Ψ production from nuclei, study of the propagation of color charges and dipoles and of the production of dilepton pairs in the quark-gluon plasma, and investigation of the freezeout of hadrons from hot, dense matter.

Particle Theory

Research in particle theory at MIT seeks to extend and unify our understanding of the fundamental constituents of matter and the theory which governs them. During this past year, significant advances have been made in the areas of particle phenomenology, cosmology, and the theory of fields and strings, as well as in the more general areas of quantum mechanics and mathematical physics.

Spin dependent structure functions, which specify the distribution of quarks and gluons in a hadron of a specific spin orientation, are expected to become accessible experimentally and are therefore of particular importance in particle phenomenology. They have been a continuing source of interest to members of our group and the nuclear theory group and a topic of fruitful collaboration. In the context of the parton model, it has now been understood how to specify completely the full set of independent information about particle structure that can be obtained from measurements in which spins are polarized transverse to the direction of the incident particle. In addition, it has been shown how to exploit semi-inclusive lepton scattering as a new source of information. This new understanding will be crucial in planning future experiments.

In collaboration with members of the nuclear group, a new model has been developed for the description of hadron structure. This model is motivated by the understanding gained from lattice gauge calculations about the dominant role that should be played by the non-perturbative enforcement of the color version of Gauss's law. In addition, a new

formulation of Yang-Mills field theories promises a different insight into the consequences of the non-Abelian aspects of this law.

Investigations at the interface of quantum field theory and cosmology have continued to address the fundamental problem of how fluctuations and density perturbations in the inflationary phase of the big bang generate the large scale structure observed in the present universe. The recent COBE observation of fluctuations in the microwave background highlights the importance of this problem and provides a new impetus towards its resolution.

To deepen our understanding of general relativity, the existence of "time machines" or closed time-like paths has been investigated in gravity theories in two space dimensions. Although such paths exist as formal solutions, in the cases which have been studied, the systems which allow such solutions are shown to be unphysical or impossible to create from a physical initial condition. Another topic under study at the interface of particle physics and cosmology is the problem of baryon number violation at the scale of the weak interaction versus a violation at the grand unified scale.

In quantum field theory, the method of "differential regularization" for carrying out the ancient task of regularizing and renormalizing divergent Feynman diagrams has been developed. Up to now there has been no such single method which was effective for all interactions, and this defect has now been remedied.

Understanding the role of topology and quantum symmetry breaking in field theory is an area in which members of this group have had a continuing interest and made seminal contributions. Current work addresses field theories in two space dimensions, with particular emphasis on quantum gravity and the theory of the oval vortex-like structures known as anyons which are believed to play an important role in physical two-dimensional condensed matter problems.

Research in the theory of strings and related problems has flourished with the infusion of new faculty in this area. The general field theory of closed strings developed previously has now been applied to a solvable model, and effort is underway to remove its background field dependence. Symmetry breaking in topological field theories has been investigated and the roughening of the two-dimensional world sheet has been clarified by the proof that the surface is self-similar. The study of thermodynamics in string theory has led to the study of the role of temperature in gravity theory and addresses the problem of the Hawking temperature and radiation from black holes.

With the addition of a new faculty member, studies of the phenomenological consequences of the standard model are now being pursued in new directions, including both precision tests of the electroweak interaction and study of the phenomenological implications of possible extensions of the standard model. Such studies will be crucial to the physics of present and future experimental programs at Fermilab, LEP, HERA, SSC, and the LHC.

Much of the vitality of the Center for Theoretical Physics arises from broad interests in general problems in theoretical physics. Thus, nuclear and particle theorists have also addressed a variety of general topics in mathematical physics, field theory, quantum mechanics, many-body theory, statistical mechanics, and astrophysics. Recent examples range from the study of novel quantum mechanical bound states for particles in twisted tubes to an analysis of the instabilities in systems with long-range interactions like plasmas or stellar systems.

J. Negele, Director

SUMMARY OF SUPPORT

Participants in the various research programs during the past year amounted to approximately 423 people. This includes 44 academic staff members, 93 graduate students, and at least 35 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 136 employees in supporting categories such as engineers, technicians, machinists, computing and administrative personnel. At least ten Ph.D.'s, and two B.S.'s were awarded based on thesis research within LNS.

Support during fiscal year 1992 from the contract with the US Department of Energy (DOE) is expected to total $26,993,000. This sum breaks down as follows: Operations costs (salaries, wages, materials, services, travel, and overhead) were $20,853,000; of this $7,310,000 was for experimental and theoretical high energy physics,$11,493,000 was for intermediate energy nuclear physics for the support of the Bates Linear Accelerator Center and research programs at Bates and elsewhere, and $2,010,000 was for nuclear structure theory, solar neutrino, and for heavy ion experiments and $40,000 for SSC R&D. Equipment costs are expected to total $4,610,000; of this, $2,885,000 will be for High Energy physics and $1,725,000 for medium energy and heavy ion physics. A total of $1,530,000 will be expended for accelerator improvement and, general plant construction projects associated with the Bates Linear Accelerator Center. Support for other programs within LNS,including support from other institutions and laboratories for collaborative work undertaken directly by LNS, is expected to total about $1,120,820.

R. P. Redwine, Director, LNS

George R. Wallace, Jr. Astrophysical Observatory

FACILITIES

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 5.5-inch astrograph, and a small building that houses a workshop, darkroom, computer facility, and observers' quarters. Instruments include the "SNAPSHOT" high-speed dual-CCD photometer, conventional photometers, photographic cameras, and a spectrograph.

Upgrades to Observatory facilities during the past year included the installation of a DEC RISC workstation that allows the processing of CCD frames at the Observatory, as well as at a campus computer facility though a high-speed optical fiber network. Richard Meserole replaced the Right Ascension drive motor in the 24-inch telescope. The Observatory also installed several new small CCD systems, including a Photometrics Star 1 and a Spectrasource Lynxx. Macintosh computers were acquired to run these systems and perform data analysis. The new systems will be used for both teaching and research.

PERSONNEL

The Observatory Director, Professor James L. Elliot, was on sabbatical leave last year. Principal Research Scientist Heidi B. Hammel served as Interim Manager in his absence. James Bauer was hired to perform on-site observations, replacing Marcus Babzien who left to attend graduate school.

ACADEMIC ACTIVITIES

Last year 22 students in subject 12S23 (Observing the Stars and Planets) used the Observatory for their laboratory work. An additional 4 students used the observatory facilities for course 12S24 (Advanced Observations of Stars and Planets). The subject 8.287J-12.117J (Observational Techniques of Optical Astronomy) was not offered last year due to Professor Elliot's sabbatical.

An open house held during MIT's 1992 Independent Activities Period attracted over 40 people, mostly MIT undergraduates. A second open house was held for students in Dr. Hammel's high school astronomy class, taught through MIT's High School Study Program. About 30 people (including parents, siblings, and friends) attended.

RESEARCH PROGRAMS

Stephen McDonald and Professor Elliot completed their astrometric search for stars that could be occulted by Triton during 1990-95, using analyses of CCD frames obtained at the Observatory's 24-inch telescope last year. They found 129 potential candidates, from which they predicted 30 observable occultations from earth. The astrometric precision achieved in this work was 0.2 arcsecond. These stellar occultations will be the only method for probing Triton's tenuous atmosphere with high spatial resolution in the foreseeable future. The results of the search were accepted for publication in the Astronomical Journal.

Astrometric and photometric observations in support of the Hubble Space Telescope were made and are continuing, with Graduate Student Amanda Bosh coordinating the effort. The undergraduates carrying out the observations — Reba Bandyopadhyay and Christina Ansoorian — are participating in the Undergraduate Research Opportunities Program and are being supported by NSF's Research Experiences for Undergraduates. Ms. Ansoorian is also working with Mr. McDonald and Professor Elliot on a study of occultation candidates of Saturn's satellite, Titan.

Graduate Student Steve Slivan, working with Professor Richard Binzel, used 13 nights of 24-inch telescope time to observe the rotational lightcurves of the asteroids 263 Dresda and 321 Florentina. He plans similar observations of 462 Eriphyla and 277 Elvira this summer.

HEIDI B. HAMMEL

CHAIR OF THE FACULTY

THE FACULTY POLICY COMMITTEE

This year the Faculty Policy Committee (FPC) devoted much of its time to examining the faculty committee structure and revitalizing the roles of some committees to meet the changing needs of the faculty and the Institute.

In fulfilling its charge to represent the interests of the faculty, FPC worked to stay informed about issues that affect faculty members as well as the MIT Community and society at large. These discussions covered many topics, such as:

- President Charles M. Vest visited FPC to mark the completion of his first year as President and to outline recent achievements and initiatives for coming years, including: creation of the Global Environmental Council to strengthen MIT's international commitments; efforts to attract more women and minority faculty to the Institute; insuring academic excellence and productivity through improvements to K-12 education; and rebuilding trust in science and technology by establishing clear guidelines for academic honesty at all levels of scholarship.

- FPC held several meetings with Provost Mark S. Wrighton to exchange views on topics of particular interest to the faculty. These conversations focused on how the Institute can address changes in Federal funding for indirect costs and graduate student tuition, allocation of resources for faculty travel expenses, and faculty retirement.

- Dean of the Graduate School Frank Perkins visited FPC to give his perspective on the RA/TA tuition crisis, and to discuss a number of other concerns, such as: health care costs for graduate students and their families, the growing demand for all-but-dissertation status for graduate students, and changing Federal guidelines for international students.

- FPC kept abreast of developments in MIT's interaction with the Federal government. FPC developed an understanding of ongoing negotiations on indirect cost rates, graduate student tuition funding procedures, and the Department of Justice lawsuit on financial aid, and deliberated about how these complicated issues might effectively be communicated to the Faculty.

- As in many other areas of MIT, FPC discussed how to preserve and improve upon the quality of teaching at MIT, and stated its concern that teaching has yet to become a significant factor in the tenure process. The Committee observed that some areas of MIT are taking steps to change this situation and stated its hope that these efforts will succeed.

- Harassment issues arose in several forms throughout the year, and FPC conferred on how to heighten awareness of harassment and foster behavior that is appropriate to a university community. The Committee discussed the perceived effects of harassment on graduate students and junior faculty as well as the dangers of harassment policies that impinge upon individuals' right to free speech.

FPC also heard from and coordinated the work of several committees:

- Associate Provost Sheila E. Widnall visited FPC to discuss the Report of the Committee on Academic Responsibility. She and Professor Nelson Y-S Kiang, Chair of the Committee on Discipline, presented their views on how research institutions can prevent academic dishonesty, and how allegations of misconduct can best be pursued and adjudicated.

- Members of the Committee on Outside Professional Activities (COPA) visited FPC to consider a plan to review the current policies and reporting procedures for outside professional activities. FPC outlined

its concerns, particularly with respect to the appropriate use of graduate students and support staff. FPC expects to discuss COPA's recommendations about these polices in the coming year.

- FPC reviewed the charge to the Ad Hoc Presidential Committee to Review the Academic Calendar. The Committee was created and appointed by the President to resolve increasing time constraints identified during last year's discussion of the Biology Requirement. FPC expects to review the Calendar Committee's recommendations in the fall.

FPC responded to the reorganization of the Office of the Provost by reviewing and redefining the work of some faculty committees, which resulted in several actions by the Faculty:

- FPC reviewed the memberships of several faculty committees, and corrected them to reflect the merging of the Offices of the Dean for Undergraduate Education and the Dean for Student Affairs under Arthur C. Smith. The Faculty passed a motion on May 20 making the appropriate adjustments to the *Rules and Regulations of the Faculty.*

- The Committee on the Undergraduate Program (CUP) required special attention due to the death of its first and only chair, Professor Margaret L. A. MacVicar. In order to preserve its role as an advocate for innovation in undergraduate education, CUP was reorganized to refocus its energy as a faculty committee rather than a vehicle for the Dean for Undergraduate Education and Student Affairs. The Faculty voted a motion on May 20 approving the new membership structure. CUP and FPC will review CUP'S duties and its relationship to other faculty committees this fall.

- FPC continued to search out the best way to address ex officio membership on the Faculty, and made some headway on finding alternative methods for obtaining the appropriate level of input from non-faculty members of the community. On May 20, the Faculty passed a motion empowering the Chair of the Faculty or the Chair of the meeting to give speaking privileges to administrative staff and students who are uniquely qualified to contribute to faculty discussions on particular topics. FPC will continue to wrestle with this issue next year.

- Recognizing that the annual May meeting to vote degrees has outlived its usefulness, the Faculty voted on November 20 to abolish this meeting giving the Officers of the Faculty the power to approve the degree lists. The revised rule stipulates, however, that should a dispute arise over the appropriateness of awarding any degree, a Special Meeting of the Faculty must be called to resolve the issue.

FPC kept a particularly close eye on undergraduate issues, due in part to the ongoing effort to renew its working relationship with the Committee on the Undergraduate Program. The Committee exercised it responsibility to interpret and enforce Faculty policies:

- FPC reminded faculty members of their obligation to keep the 5:00 - 7:00 p.m. time period free of academic exercises.

- The Committee approved an emergency policy in the event of MIT closing on critical academic days. This policy outlined procedures for accommodating or rescheduling key activities such as exams and registration in the event of inclement weather.

- Violations of the end-of-term regulations prohibiting comprehensive examinations during the last week of classes continue to pose a problem. The Committee recommended that this issue might be addressed when FPC discusses the report of the Ad Hoc Presidential Committee on the Institute Calendar next fall.

Professor Vandiver expressed his deep appreciation to all FPC members for their thoughtful participation on FPC throughout the year. He extended special thanks to the Committee' s departing members: Professors Robert Cohen, Jerome Rothenberg, David Gordon Wilson and Associate Provost David Litster, Mr. Peter Cebon and Ms. Colleen Schwingel (graduate and undergraduate student members, respectively).

THE COMMITTEE ON THE UNDERGRADUATE PROGRAM

This has been a transitional year for the Committee on the Undergraduate Program (CUP). The death of Dean for Undergraduate Education Margaret L. A. MacVicar in October was a source of great sadness and loss for the Committee and for all members of the MIT community who were empowered by Professor MacVicar's strength of vision.

Associate Chair of the Faculty Rosalind Williams stepped in to fill the leadership gap on the Committee and, in consultation with CUP members and FPC, worked to restructure CUP to facilitate its transition from a dean's committee to a faculty committee. In doing so, CUP and FPC took into consideration advice from the Provost and newly appointed Dean for Undergraduate Education and Student Affairs Arthur C. Smith. The legislation voted by the Faculty on May 20 implemented the following changes to the membership of the Committee: increased the number of appointed faculty members from three to seven plus the Associate Chair of the Faculty; doubled the number of undergraduate members from two to four; shifted the Chairmanship from the Dean to a faculty member; established one ex officio position for the Provost or his designate; and retained one ex officio membership for a person to be designated by the Dean.

This fall, CUP and FPC will undertake a review of CUP's duties as outlined in the *Rules and Regulations of the Faculty*. This review will seek to clarify CUP's relationship to other faculty committees and to the Dean's Office. Professor Williams will continue as Chair through 1992-3 while completing her tenure as Associate Chair of the Faculty.

While the restructuring process was taking place, CUP went about its usual business of reviewing academic proposals, some of which are in the experimental phase:

- In consultation with the Committee on Curricula, CUP approved modifications to the chemical engineering degree program which were designed to increase its chemistry content. This increase led to a conflict with existing faculty rules regarding the number of subjects a department may specify for its undergraduates. After lengthy debate and review, CUP and COC agreed that the Department of Chemical Engineering may advise freshmen intending to major in chemical engineering to fulfill the chemistry requirement by taking 5.11 rather than 3.091. This compromise allowed the department to remove 5.11 from its list of required subjects, making room for more advanced chemistry subjects. This decision is ground-breaking in that it allows a department to recommend that students make a specific choice of a core subject during their freshman year.

- CUP authorized an experiment designed to introduce more flexibility into HASS-D subjects by permitting students to complete a take-home final exam rather than take a three-hour scheduled final exam. The Committee will review the results of the experiment next year.

- CUP reviewed the results of the first administration of the freshman math diagnostic examination. Preliminary results showed that the diagnostic was successful in helping freshmen choose the appropriate math subject for their first term. The math diagnostic also resulted in the creation of a new elongated version of introductory Physics (8.01L) designed to postpone aspects of physics that use calculus so that students will be exposed to those concepts in 18.01 before they encounter them in physics.

- The Department of Electrical Engineering and Computer Science presented its proposal for a five-year degree program to CUP . Many members of the engineering faculty believe that the rapid expansion of engineering technology requires additional time in the curriculum to teach students new ideas and skills needed in the professional world. The Committee believes that the issues surrounding this proposal are pivotal to the future direction of MIT's undergraduate curriculum. CUP will continue to participate in discussions of these matters as the Department (and perhaps others in the School of Engineering) finalizes its proposal during the coming year.

- The time study authorized by CUP in 1990-91 was implemented on a limited scale this year. It focused on the way MIT freshmen allocate their time among academic and extra-curricular activities. Preliminary results show that the ratings published in the *Course Evaluation Guide* are generally

accurate. CUP authorized a continuation of the study for 1992-3, with special emphasis on the time students spend studying freshman core subjects in conjunction with some subjects that have a reputation for being time-consuming, such as 6.001.

- Professor Suzanne Flynn, Chair of the Committee on the Writing Requirement (CWR), presented to CUP the latest revisions of the Writing Requirement and of the structure of CWR.

CUP also heard reports from committees and individuals throughout the year addressing a broad range of topics:

- Early in the year, CUP met with Provost Mark S. Wrighton to discuss the restructuring of the Dean's Office and his philosophy on undergraduate issues. The Provost expressed his support for the alternative freshman programs and renewed emphasis on undergraduate teaching.

- As a follow-up to the discussion with the Provost, CUP met with the directors of the Experimental Study Group, the Integrated Studies Program, and Concourse to consider how these programs can be maintained and further enriched and possibly expanded.

- Chaired by Associate Provost Sheila E. Widnall, the Committee on Academic Responsibility articulated many of the concerns about the culture of academic dishonesty that seems to be growing at MIT. Professor Nelson Y-S Kiang, Chair of the Committee on Discipline, also contributed to dialogues on how to address academic honesty on a broad scale, including the possibility of establishing an honor code.

- Dean Philip S. Khoury visited CUP to discuss the Interim Report on the HASS-Distribution Requirement. The HASS-D Overview Committee prepared a number of recommendations that will be implemented before the final review of the HASS-D requirement in 1994. The Overview Committee's recommendations included adjustments to the following HASS-D areas: the lottery system, the languages and literature section of HASS-D, the writing component, licensing for subjects, and final examinations.

- The annual report on the educational commons was presented by Dean Leslie Perelman of the Office of the Dean for Undergraduate Education and Student Affairs. CUP agreed with the Dean's Office that the report is useful but that the responsibility for gathering and examining the data should be shifted to the academic departments and that the annual reporting process to CUP will thus be discontinued. CUP recommended that faculty participation in commons activities should be included in each School's five-year plan.

- CUP concluded a number of formal and informal discussions of undergraduate teaching at MIT, including a follow-up discussion of the Institute Colloquium on Teaching Within a Research University.

- CUP engaged in preliminary discussions of several initiatives expected to take full shape next year, including minors in science and education; a new freshman studies program with special emphasis on biology; and the continued development of the new core subject in biology (7.01).

In response to the motion passed by the Faculty in May 1991, which mandated a committee to review the General Institute Requirements and the academic calendar, the President and the Chair of the Faculty chose to appoint a separate committee to examine the academic calendar and subsequently asked CUP to outline the issues that a GIR committee might address. CUP devoted its January Work Session and many of its meetings to this topic, consulting a number of faculty members in the process. Although formal recommendations will not be issued until the coming year, CUP 's basic conclusions about the General Institute Requirements are best addressed by breaking them down into three more specific areas:

- the challenge of restructuring engineering programs, which are already overcrowded, in order to prepare MIT engineers adequately for a rapidly changing world;

- the challenge of integrating more experimental or hands-on experience into the curriculum; and
- the challenge of transforming an extremely diverse group of high school students into productive MIT students in the freshman year.

During the coming year, CUP will outline specific proposals designed to confront these challenges.

Professor Williams and the Committee would like to recognize the contribution of departing CUP members: Professors Hartley Rogers and Lorna Gibson, Dean Margaret Enders, Dr. Gregory Jackson, Mr. Rahul Shah, and Ms. Sophia Yen (undergraduate members).

In order to address the complex issues related to the General Institute Requirements and the reorganization of CUP, the Committee engaged a number of additional faculty and staff members to assist in its deliberations during the year. CUP would like to extend its thanks to the following individuals for their participation: Professors Harold Abelson, William Durfee, Anthony French, Robert Jaffe, Lorna Gibson, Winston Markey, Travis Merritt, William Orme-Johnson, and J. Kim Vandiver.

OTHER FACULTY COMMITTEE REPORTS

Chairs of the Faculty committees have submitted summaries of the major agenda items addressed during the past year:

Most of the efforts of the **Committee on Academic Performance** (CAP) were devoted to its responsibilities to review the records of students with poor grades or insufficient progress toward a degree and consider petitions for variations in the rule.

CAP continued the policies established last year for handling petitions to exceed the freshman credit limit. ***No*** exceptions were granted to the 54-unit limit for the first term. In the second term, the Committee did not receive any petitions that were sufficiently well-documented to warrant approval of exceeding the credit limit of 57 units.

In a related matter, CAP discussed a problem with first term freshman credit limits arising from students taking a Freshman Advisory Seminar (FAS) who are also enrolled in Seminar XL (both the FAS and XL carry six credit units). A freshman enrolled in the normal 4 subjects plus a FAS and XL would exceed the 54-unit credit limit. Deans J. J. Pitts and Travis Merritt sought blanket approval for exceeding the credit limit for this group of students. CAP unanimously approved this request. In the future, the Dean's Office will provide CAP with a list of students enrolled in both FAS and XL at the start of the fall term.

The **Committee on Student Affairs** (CSA) serves as a forum for students (it now has full graduate and undergraduate representation), faculty, deans and associate deans in the Office of the Dean for Undergraduate Education and Student Affairs (ODUESA) to discuss and study a broad range of issues that affect student life. CSA had a relatively active first semester with regular monthly meetings.

CSA continued to focus on two issues under review by subcommittees. One subcommittee chaired by Professor John Carroll researched the question of diversity and mutual respect on campus, and a final report is expected soon. Professor George Verghese chaired a subcommittee devoted to the issues of international students and international experience for all students at MIT. Notable events included two dinner gatherings to which representatives from all international student clubs were invited. This subcommittee will continue its work this fall.

CSA also held a special meeting with by Dean Arnold Henderson of Student Assistance Services in the ODUESA, on the issue of handicapped students and the implications of the American Disability Act which will become effective in July 1992.

Despite these activities, there was a growing concern over the foci, effectiveness, and vitality of CSA , or lack thereof. One telling symptom was the uneven attendance of some members at the regular meetings, particularly ODUESA representatives. During the spring term, the Chair and select members began a process to better define the role of CSA and the major student affair issues it should address both short and long term. Part of this process involved individual interviews with the deans and associate deans in the ODUESA and the Graduate School. This activity is expected to continue through the summer. Next fall, CSA plan to expand this dialogue to include representative student and living groups.

The **Committee on Nominations** nominated 35 colleagues for service on faculty committees, including the Chair-elect of the Faculty (Professor Robert L. Jaffe). As in past years, the Committee nominated faculty from all Schools and Departments so as to achieve a good representation of the educational programs of the Institute in the deliberations of the 14 faculty committees.

The **Harold E. Edgerton Award Selection Committee** issued a call for nominations which was distributed by direct mail to all faculty and by announcement in *Tech Talk*. Nominations were reviewed and debated and an awardee, Professor Henry Jenkins of the Literature Faculty, was selected unanimously. The Committee citation presented at the April 15 Faculty Meeting cited Professor Jenkins' recent work on the effect of audiences on the mass media of television and the movies. The Committee noted that "Professor Jenkins has put film and media studies on the map for undergraduates. He seems to do the work of a small department. He has created many new subjects, nurtured majors, and designed special topics or reading courses for film-media majors and minors."

The **Committee on Faculty-Administration** had several discussions about the need to protect freedom of speech rights in the Institute's sexual harassment policy. It also initiated an examination of the Institute retirement plan to determine whether or not the plan's information policies can be improved.

The **Committee on Corporate Relations** (CCR) serves as advisor to the administration regarding MIT's relations with both national and international corporations. CCR is particularly concerned with faculty perspectives on research policy issues. The Committee's activities in the past year have focused upon three major topics: support for research and the opportunities for increasing industrial research; the national need for improved industrial competitiveness; and opportunities for increased contact with non-US industries, including Eastern Europe.

CCR has worked closely with the staff of the Office of Corporate Relations and the Industrial Liaison Program (ILP) in considering the above issues. There appear to be significant opportunities for developing contacts between US corporations and the faculty using the established relations within the ILP. There are now about 50 international members of the program from Europe alone. The Committee will continue discussions on overseas relations into the future and is interested in providing appropriate faculty input into decision-making regarding the development and maintenance of such relations.

The **Committee on the Library System** (CLS) reviewed and made suggestions for improvements in the handling of non-book collections (videotapes, films, and slides). CLS also debated suggestions for improvement of library security to reduce losses and damage to materials. Other issues considered by CLS include: library funding and the continued increases in periodical prices which are expected to lead to more cancellations within a year; progress in the current study of how users gather information; and electronic publishing and the libraries of the future.

During the year the **Committee on Discipline** (COD) heard charges brought against thirteen students (this group included undergraduates and graduates). One case was for unauthorized use of the Institute name

to purchase items for personal use, the rest for various kinds of academic dishonesty such as plagiarism, copying work of other students without permission, changing answers on examinations before asking for re-grading, and using unauthorized material during examinations. Three students were suspended for up to two years, the rest received probation for various durations. All charges were brought either by members of the faculty or the administration.

Spurred by the Course 1.00 affair two years ago, the COD decided to become proactive in addressing issues of cheating defined as "claiming credit for work not done." Some of these activities were:

- In December 1991, COD sent a letter to all students reminding them of the need to behave honestly. This action was followed by meetings with various groups of student leaders and representatives in order to learn how students feel about the issue.

- The Chair met with the Academic Council, FPC, CUP, and the President to exchange ideas on such issues as the possible role of an honor code at MIT, changes in policies and procedures for handling discipline, and possible modifications in faculty-student relationships that might promote honest behavior.

- Members of the Committee brought up issues of fairness and appropriateness in the handling of academic misconduct by individuals or departments at the Institute.

- The Committee met with the Registrar to explore how various disciplinary notations are recorded on transcripts.

- Data on how disciplinary matters are dealt with at other educational institutions were collected and discussed.

- The Committee began working with the Office of the Dean for Undergraduate Education and Student Affairs on an MIT Colloquium to be held on October 21, 1992, that will focus on issues of academic honesty inside and outside a university setting.

COD intends to carry forward these initiatives to the coming academic year.

The **Committee on Outside Professional Activities** (COPA) has been meeting regularly throughout the year in response to the Faculty Chair's request that it review the current status of faculty outside professional activities, the appropriateness of relevant sections in *Policies and Procedures*, and the various mechanisms used to monitor these activities and resolve problems. One important objective is to raise awareness amongst our faculty of the tremendous importance of appropriate attitudes and behavior related to outside professional activities. The Committee has identified several areas of concern: excessive time away from MIT; conflicts between MIT research, consulting in related areas, and faculty forming companies; use of students in outside activities; and use of MIT staff to support outside activities.

Following a review of the relevant sections in *Policies and Procedures*, COPA has revised the section that relates to involvement of students in outside professional activities to clarify the important issues and procedures that must be followed, and has drafted a section on "Use of Support Staff in Outside Professional Activities" to provide guidance in this problematic area. The Committee is also modifying the form used each year by faculty to report the extent of their outside professional activities so that department heads can monitor these activities more effectively.

The Committee found much support for the benefits of faculty outside professional activities, and concluded that the overwhelming majority of faculty are thoughtful and responsible in their pursuit of these activities. However, the complexities involved and the potential for problems require clearer statements of MIT policies and greater awareness amongst the faculty of those policies.

The members of the **James R. Killian, Jr. Faculty Achievement Award Selection Committee** met on four occasions to select the recipient of the 1992-93 Killian Award. The Committee received eight nominations, and four of these nominees became finalists. Our attention then concentrated on obtaining further information and advice from the faculty to select the winner. It was a difficult choice to make, given the remarkable quality of everyone being considered. Finally, the Committee selected Professor Peter S. Eagleson for his outstanding contributions to the field of hydrology, an area of knowledge that he helped elevate to a respectable, scholarly discipline, as well as his contribution to the profession as a whole and to the MIT community in particular.

The Committee's citation noted that Professor Eagleson is "internationally recognized as a world leader in hydrology." Underscoring the importance of hydrology research in these environmentally-conscious times, the Committee observed that Professor Eagleson has "led the extension of hydrology from the local into the regional and global scales. On these scales the budget of water is a fundamental part of the climate machine, and changes on these scales underlie much of the present concern about the effects of climate change on society."

The **Committee on Undergraduate Admissions and Financial Aid** (CUAFA) completed its review of the admission of transfer students. A report was prepared based on replies to a questionnaire sent to all departmental undergraduate officers in May 1991. In summary, most departments feel that the number of transfer students is about right, that the presence of transfers enhances the diversity of majors in a department, and that the same or academically more stringent criteria should be used for their admission as for the admission of freshmen.

CUAFA took up the continuing problem of increasing faculty participation in the admissions process. The Chair of CUAFA and the Provost jointly wrote a letter to all department heads asking them to nominate two or three of their faculty members to serve on an admissions task force, members of which were responsible for reading at least 20 to 30 admissions folders. This effort resulted in modest success: 35 faculty members from 15 Departments read four or more folders each, for a total of 783 faculty reads. These numbers represent an increase in the number of faculty readers for 1991 (23 readers, 616 folders), but a decrease from those in 1990 (37 readers, 988 folders).

Other CUAFA activities included reviewing a somewhat controversial proposal for a "Minority Scholars Program" at MIT, discussion of the style and content of a proposed new Admissions Office video with the filmmakers, and several discussions of problems and policies associated with student financial aid.

As in previous years, the **Committee on Curricula** (COC) exercised oversight of a number of administrative transactions, reviewing proposals for new, changed, and deleted subject offerings and responding to student petitions for variances regarding the General Institute Requirements for degrees. COC views its role as that of the reasonable person interpreting the faculty regulations in the light of intentions, gleaned from the legislative record, and from the record of previous COC decisions.

This past year, COC had a number of discussions with the leadership of several engineering departments which are in the midst of re-evaluating their undergraduate programs: Chemical Engineering has extensively remodeled their curriculum to include a much amplified emphasis on chemistry basics; Electrical Engineering and Computer Science is experimenting with categorizations of their Protean enterprise, of a philosophical bent that would have no doubt delighted Roger Bacon; Aeronautics and Astronautics is dealing with arguably the most vividly cross-cultural set of skill and knowledge requirements faced by baccalaureate students. These events have been termed "The Charge of the 600-pound Gorillas" by some COC members, who see the Committee's role as facilitator, occasionally and gently reminding colleagues of the ever-present pace and pressure issue as epitomized by the credit limitations and breadth requirements MIT has generally imposed on all undergraduate programs. (One wonders how many other institutions face the simultaneous phenomena of academic bulimia and IHTFP). All of these momentous changes will surely involve general faculty attention and debate during the coming year.

Another ongoing initiative is the reevaluation of the credit and content (theory versus rehearsal) aspects of the HASS performance courses. Assisted by Associate Provost Ellen Harris, these issues are being addressed by the faculties involved, and COC expects a revised set of subjects to arrive next fall. COC has been thanked by the leadership of this area for its catalytic role in this process.

During the academic year 1991-92 the **Committee on the Writing Requirement** (CWR) was quite active in carrying out its charge from the Faculty to oversee the undergraduate writing requirement and to foster instruction in clear, effective writing throughout the undergraduate curriculum. During the summer of 1991, the Committee reviewed sample Phase Two papers from academic departments. On the basis of that review, the Committee, with the unanimous concurrence of departmental coordinators, has abolished the category of Marginal Pass from both Phase One and Phase Two papers, beginning July 1, 1992. The Committee, with the concurrence of CUP, also modified the conditions under which students receive Phase One credit for completing a specified writing subject. The Committee, also with the approval of CUP, is now requiring all entering undergraduates who have not already completed Phase One to take the Freshman Essay Evaluation during their first term at the Institute, beginning with the class of 1996. The purpose of this change in policy is to ensure that potential writing problems are diagnosed early in a student's career at the Institute. The Committee has also authorized several experiments concerning the scoring and grading of the Fall 1992 Freshman Essay Evaluation.

In January, CWR hosted a luncheon for departmental writing coordinators which included a lively and productive discussion of various issues concerning writing at the Institute. Beginning with the academic year 1991-92, the Committee now awards the Park A. '27 and Ann L. Hodges Prizes to outstanding Phase Two papers in addition to the outstanding Freshman Evaluation essays. This year three prizes were awarded to members of the Class of 1995 for their evaluation essays, and two prizes were awarded to upperclass students for their Phase Two papers.

CWR has begun consideration of two long-range initiatives: first, it is exploring new ways to incorporate writing and instruction into all parts of the undergraduate curriculum; second, it is exploring specific ways that instruction in oral communication can be integrated into the Writing Requirement.

The Committee expresses its gratitude to Professors Martin Diskin and Jeffrey Feerer, who are leaving the Committee after completing their three-year elected terms.

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: George F. Koster (Academic Performance), Kent F. Hansen (Corporate Relations), William H. Orme-Johnson (Curricula), Nelson Y-S Kiang (Discipline), Harvey Sapolsky (Faculty-Administration), Gerald E. Schneider (Library System), Elias P. Gyftopoulos (Nominations), John B. Heywood (Outside Professional Activities), John S. Carroll and Dick Yue (Student Affairs), June L. Matthews (Undergraduate Admissions and Financial Aid), Suzanne Flynn (Writing Requirement), Irwin Oppenheim (Edgerton Award Selection), and Arnoldo Hax (Killian Award).

J. KIM VANDIVER
SARAH T. CAMPBELL

SENIOR VICE PRESIDENT, OPERATIONS

Energy conservation continues to be a major focus at the Institute. During the year, MIT joined the Green Lights Program. This program, sponsored by the Environmental Protection Agency (EPA), is aimed at reducing air pollution caused by electric-generating plants by reducing the need for electricity. By joining this program, the Institute has committed to installing energy efficient lighting in 90 percent of its buildings, where it is cost effective, over a five-year period.

In other conservation efforts, several water saving initiatives were implemented including the installation of low flow toilets, elimination of once-through cooling systems, and the use of water for irrigation from the Charles River. As a result of these and future efforts, the Institute should realize a 25 percent savings in water usage.

Progress continues on the Institute's largest construction project, the Biology Building, with construction of the foundation being completed during the year. Other major design and construction activities that took place during the year included reconstruction of the concrete plaza surrounding the Compton Building (Building 26), replacement of the roofing system on Building 1, and a continuation of the design and renovation activities at the former Cabot Building (Building E56) in the areas that will house the Dibner Institute and Burndy Library.

Issues associated with ever increasing environmental, health, and safety regulatory requirements continue to necessitate close monitoring to ensure that the Institute remains in compliance. As a result of recent passage of the Americans with Disabilities Act (ADA), which requires that any employer with 15 or more employees provide reasonable access for handicapped individuals, the Institute has established a committee to identify areas that may hinder access and make recommendations for their elimination.

Progress in achieving Affirmative Action goals remained a concern. Some success was achieved during the year with the appointment of two underrepresented minorities to the administrative staff. During the last two Affirmative Action reporting periods, seven underrepresented minority individuals were appointed including the two who were mentioned above. We remain absolutely committed to fulfilling the Affirmative Action goals of the Institute.

James W. Coleman, Director of Graphic Arts Services, retired at year's end after 39 years of exemplary service. Albert K. Paone will succeed him.

Following are individual department reports.

WILLIAM R. DICKSON

Campus Activities Complex

The coordination and operational support of campus events is a major focus of the Campus Activities Complex (CAC). During the year, event planning, support, and supervision included over 8,000 scheduled events with combined attendance of approximately 300,000. Among the major Institute events the CAC assisted with this year were the MIT Community Ball, the National Technology Initiative Conference, the 1992 Commencement Ceremonies, and the Games of Ancient Grease presented by WBUR's Car Talk radio program.

Several spaces assigned to the CAC underwent renovation this year. These included new lighting in the MIT Chapel and West Lounge, repair and reupholstering of Kresge Auditorium seating, and the resurfacing of the auditorium floor. During the fall, the Medical Department held a gala grand opening for the MIT Optical Shop. In addition, the Networks Restaurant was renovated and their menu and services were modified to complement student preferences. The MIT Computer Connection also updated its space in order to provide greater versatility on the sales floor.

The CAC also introduced three new programs for students: Timeout, which engaged students and representatives from all areas of the Institute community in casual conversations; an IAP class, Leadership and Business Skills in the Out-of-Classroom Environment which was presented in cooperation with the Alumni Association and the Leadership Foundation; and SafeBreak, offered just prior to spring recess, which encouraged students to think about safety while on vacation. These student educational programs complemented the traditional series of events.

The CAC's Vendor Program increased in popularity this year by selling a wide range of products and services. This resulted in a 30 percent increase in income when compared with last year. This revenue source continues to fund the Stratton Student Center Information Desk.

The MIT Corporation honored a former member of the Campus Activities Complex staff by dedicating the lounge on the fifth floor of the Stratton Student Center to Conor Moran, a 30-year employee, who retired last year. Frank Winsor, Associate Director of Operations, retired at the end of the year year after 29 years of devoted service.

PHILLIP J. WALSH

Campus Police

The Campus Police Department continued to serve the MIT community with 24-hour professional police and emergency medical services. In addition, the Crime Prevention Unit and Special Services Division continued to provide crime prevention education and assistance with problems such as landlord/tenant disputes, consumer fraud, small claims court cases, and abuse and harassment situations.

There were a total of 1,788 complaints (situations which required the recording of an incident by a police report) recorded this year. Of these complaints, 28 were in the crimes against person category. Campus Police Officers made 80 arrests on MIT property this year.

Larceny again continued to be the largest category of crime with which the Institute had to contend this year. The total number of reported incidents of larceny of Institute property was 159, a 20 percent decrease when compared with last year. Computers and computer components were, once again, the most frequent type of Institute-owned property stolen.

Personal property (non-residence) thefts were up 33 percent with 406 incidents totaling losses of $63,351. Wallets and purses again led the list of items stolen.

The number of residence hall losses was down 6 percent from last year with a total of 94 reported thefts. However, the total dollar loss of $30,806 was slightly higher than last year's figure.

Motor vehicle thefts increased this year with a total of 66 vehicles stolen.

This year, emergency medical service transports totalled 2,530 (including emergencies, transfers, and medical shuttles).

The Campus Police Safety Shuttle service, A Safe Ride, provided 29,494 personal safety escorts during the year.

The MIT Campus Police Department looks forward to continuing to provide the community with professional police and emergency medical services in the coming years.

ANNE P. GLAVIN

Endicott House

A substantial portion of the life safety improvements planned for the main house last year were implemented. These included the installation of sprinklers in the bedrooms and associated corridors, the dining rooms, kitchen, utility rooms, and storage areas. The secondary stairway,which runs from ground level to the third floor in the service wing of the house, was enclosed with automatic fire doors and equipped with appropriate exit signs and early warning devices. The second phase of the project, which will include installing sprinklers in the remaining public spaces, enclosing a major stairwell, and providing new egress doors will be undertaken next year.

The adjacent Stearns Estate, which was previously willed to MIT, was transferred to the Institute during the year. The estate includes a large house with 13 acres of land and several out buildings. The question remains as to the appropriate use for the property. The matter is under study at the present time.

A five-acre parcel of land given to MIT roughly 20 years ago by Russell Stearns was set aside for residential development. Approval was granted by the Town of Dedham for the development of three house lots. An attractive four-bedroom Colonial was constructed on the first lot and is currently for sale. The proceeds from the sale will be utilized to help fund the life safety improvements currently underway. Should additional houses be built, the proceeds would be used to endow a fund for other capital improvements at Endicott House.

During the year, major changes were announced by the School of Management regarding the Senior Executive Program which is conducted each spring and fall at Endicott House. Beginning with the fall 1992 program, the class size will be decreased and the length of the course will be shortened from nine to eight weeks. In addition, the mid-program field trip will be extended from one to two weeks. Additional changes include shifting the spring program later in the year beginning in 1994. These changes will have a considerable financial impact on the operation and represent a marketing challenge to fill the lost occupancy.

Fewer than usual capital projects and improvements were made during the year. Projects which were deemed essential included removal of a second underground fuel storage tank, installation of a safety rail in the back driveway parking lot, repairs to and painting the swimming pool, replacement of kitchen china and linens, re-setting of the main house terrace steps, and miscellaneous structural repairs to the Brooks Center facility. Also, modifications were made to the house's underground fuel storage facility to comply with rules and regulations recently enacted by the Town of Dedham.

From a statistical standpoint, there were 38 overnight conferences held at Endicott House lasting from one night to the nine-week Senior Executive Program. Institute-related activities accounted for 26 of these residential groups, six were from other non-profits, and the remaining six represented corporate businesses. There were 7,352 overnight guests and 28,949 meals served during the year compared with 6,256 overnights and 24,621 meals served last year.

HOWARD F. MILLER

Office of Facilities Management Systems

The Office of Facilities Management (OFMS) continued its efforts in the space accounting area with the addition of a new facilities auditor and CAD assistant. The space accounting group was particularly busy this year with expanding its CAD procedures documentation; developing audit trail procedures for CAD-to-mainframe space inventory updates, producing a manual for utilizing CAD-to-mainframe software tools, and performing two updates for distribution to departments, labs, and centers.

This year, for the first time, 1/32 scale floorplans of departmental space inventory listings were distributed to academic departments throughout the Institute. A number of other departmental requirements in the Comptroller's Accounting Office and Physical Plant were supported during the year.

During the year, the office moved to newly renovated quarters at 336 Main Street. The move was accomplished with minimum disruption due to the efforts of all the staff.

The systems development team met their schedule for converting the MIT-developed mainframe INSITE space information system functionality to a VAX workstation-based INSITE system. The conversion was completed on time and will dramatically reduce future mainframe computer usage. The entire mainframe INSITE space database has been converted to the VAX, the MIT standard reports have been duplicated, and an interactive link to INSITE-CAD has been implemented. Due to this conversion, the office was invited to demonstrate the system at A/E/C Systems' 92, the world's largest computer applications show for facilities professionals. Work has also continued toward enhancing and integrating INSITE-CAD, the MIT developed system used to digitize and maintain floorplans and CADVIEW, the system which is used by a number of MIT departments to review their floorplans and add departmental-specific text and symbol data.

Technology sharing with other universities and hospitals continues as well as the production of several facilities management industry courses and internationally recognized conferences for senior facilities managers.

KREON L. CYROS

Graphic Arts and Audio Visual Services

This year, total income for all Graphic Arts Services was $6.4 million, an increase of 5 percent compared with last year, and an all time high. The Institute Copier Program, which rents copiers to various departments, was particularly successful this year with a 9 percent increase in income over last year. Income in the Photographic and Typesetting departments was down 15 percent and 10 percent respectively while the Offset Printing department registered a 3 percent gain.

During the year, a Xerox DocuTech Production Publisher, a high speed duplicator, was purchased. This machine allows the combination of three technologies -- digital scanning, laser imaging, and xerography -- which will improve the turnaround time on jobs while maintaining a consistently high print quality.

James W. Coleman retired after 39 years in Graphic Arts. Mr. Coleman spent the last 22 years as director, only the second director in the history of the department. Albert K. Paone was appointed Acting Director.

JAMES W. COLEMAN

Housing and Food Services

This year house management programs were strengthened by providing each of the 15 house managers and the evening and night operations managers with computers and appropriate accessories. The use of this equipment has accelerated and improved house operation reporting and facilities management decision making including security, budget, student room assignment, space change, and peer networking procedures.

Development of an employee food service credit card concept continued to proceed on schedule. A consultant was contracted with to develop the software applications required to support a payroll deduction program for food service card charges by faculty and staff and implementation is expected in the fall.

A redesigned and renovated Networks Restaurant re-opened for business last September. New menu items such as fresh salads, hamburgers, steak tips, pasta, seafood, club sandwiches, and offerings from Pizza Hut Express have proven to be very popular. The change in service style which greatly increased the speed of service also seems to have been well received by a majority of the community.

Cart service in Building 4 was moved to a permanent location in Room 4-115. This move coupled with the addition of Dunkin Donuts products has made a tremendous difference in customer acceptance. Response to this kind of small, flexible, convenient food service concept has proved very positive as evidenced by increased sales. Additional locations of this type are being considered for other areas of the campus.

During the year, graduate and undergraduate student security programs continued to be emphasized throughout the Housing system. Additional support was added with the appointment of a nightwatch supervisor to a full-time staff position.

The Senior House code compliance renovation project, the major renovation project to Senior House, which began last year, was completed on schedule. In addition, phase two of the graduate housing plan to renovate Tang Residence Hall for use as a first-year graduate residence also proceeded on schedule. Completion of this project is expected next year. A new computer program lottery and graduate housing assignment system, in anticipation of the Registrar's Student Information System, was implemented this spring. This new program led to the early assignment of a very large number of new and continuing graduate students.

LAWRENCE E. MAGUIRE

Insurance and Legal Affairs

The Office of Insurance and Legal Affairs continued to pursue effective coverage of the Institute's exposure to the risk of loss by obtaining adequate insurance at reasonable cost where practical and by further development and administration of its self-insurance program. The office also administered the prosecution of MIT's claims against others as well as the defense or settlement of claims made against MIT. Along with a number of other offices, the Office of Insurance and Legal Affairs was asked to produce information by representatives of the Defence Contract Audit Agency (DCAA). The information requested from this office concerned MIT's insurance programs.

During the year, MIT purchased "all risk" form property insurance to cover all of the Institute's property. The total value insured exceeded $1.7 billion at a cost of approximately $550,000. The Institute's fleet of approximately 225 vehicles was insured at a cost slightly in excess of $150,000.

During the year, MIT discontinued its practice of purchasing its primary general liability insurance coverage from the insurance marketplace. Although a move to self-insurance was contemplated to occur over time, the continued high cost of such coverage forced an acceleration of the planned change. The primary general liability coverage (up to $1 million of any claim) has now been placed with MIT's captive, The Barton Insurance Company, Ltd. Amounts that would have been paid to a commercial carrier have been paid into The Barton Insurance Company. Excess umbrella liability, up to $100 million, has been placed with capable non-standard insurance entities. Educators Legal Liability insurance up to $10 million was also purchased. This year the total cost of liability insurance for the year was $1.375 million.

Although it remains difficult to effectively quantify since many workers' compensation claims take years to resolve, an evaluation of the first four years of self-insurance for workers' compensation indicates that savings on the order of $100,000 per year have been realized. This assessment will be determined on an annual basis.

Over 150 claims were processed over the year representing property losses by the Institute or claims attributable to liability of MIT. Reimbursements to MIT for property losses amounted to $90,000 and payments on MIT's behalf were approximately $500,000.

More than 100 students requested legal guidance, involving a broad range of legal concerns, over the course of the year.

THOMAS R. HENNEBERRY

Physical Plant Department

ADMINISTRATION
The department continued its efforts to improve customer service and overall productivity. Completed work orders were up 10 percent while overtime was down 40 percent. These accomplishments were achieved by realignment of shift schedules, elimination of downtime, and improved management practices reinforced by additional training.

MANAGEMENT INFORMATION SYSTEM
Development of the Plant Management Information System continues. A new module which will track keys was brought on-line this year and a new labor module which will track labor costs and integrate them with the Institute's payroll system is in the final stages of development. Work has begun on the accounting module which will distribute costs to appropriate building and other Institutional accounts. A new inventory module, which will be integrated with several existing modules, will be evaluated later this year.

COGENERATION PROJECT
Progress continued on the combined-cycle cogeneration project including receipt of the environmental permit. Preliminary engineering of the project has been completed including a comprehensive design criterion document, a construction estimate, and a major equipment proposal solicitation document. Negotiations with Commonwealth Gas to resolve interconnection details and a fuel transportation arrangement are nearing completion. Construction on this project could begin as early as next spring.

WATER CONSERVATION
This year there was a 14 percent increase in the combined water and sewer rates. Late in the year, the Institute was informed that an additional 25 percent rate increase could be expected next year. Several water conservation initiatives were implemented this year including the installation of low flow toilets, elimination of once-through cooling water systems, and the use of Charles River water for irrigation. It is hoped that a 25 percent savings in water consumption can be attained through conservation efforts.

ENERGY CONSERVATION - GREEN LIGHTS PROGRAM
During the year, MIT signed a memorandum with the Environmental Protection Agency committing the Institute to install energy efficient lighting in 90 percent of its buildings, where it is cost effective, over a five-year period. The Green Lights Program is intended to reduce air pollution caused by electric-generating plants by reducing the need for electricity.

REGULATORY AND CODE COMPLIANCE ISSUES
The number of environmental, health, and safety regulatory requirements continued to increase throughout the year. Continually changing legislation and regulations requires constant awareness to remain current on these issues.

UTILITY EXPANSION AND REPLACEMENT
Underground utilities serving the campus must provide ready and reliable sources of steam, domestic water, water for fire protection, chilled water for air conditioning, electricity, and sanitary and storm drains for sewage and storm water disposal. Periodic expansion and replacement is necessary to provide the degree of reliability required for the academic, research, and residential programs on campus. Two substantial projects were initiated last year. The steam and condensate lines installed under Vassar Street 30 years ago to serve the West Campus are being replaced. In addition, design of a utility corridor to serve the new Biology Building as well as the East Campus and the Northeast Sector commenced and construction should begin by next spring.

FACILITIES MAINTENANCE, CONSTRUCTION, AND RENOVATIONS
Several large-scale maintenance projects were completed this year. The concrete plaza surrounding Building 26 was replaced, the roof of Building 1 was replaced, and irrigation systems were installed covering approximately 25 percent of our green spaces. Repairs to the West Garage were also completed.

During the year, a 6000 square foot addition to the Haystack Observatory was constructed and the existing building was cosmetically upgraded. On campus, the School of Management occupied 10,000 square feet of the former A.D. Little Building, now E56, and the remaining 14,000 square feet was designed to house the Dibner Institute and Burndy Library. Construction on this project will be completed early next year. Progress continued on the Institute's largest

construction project, the Biology Building (Building 68) with completion of design documents and construction of the foundation. Construction will continue throughout next year with occupancy slated for December of 1993. When completed, the 251,000 gross square foot facility will be connected to Building 66 by a tunnel at the basement level and a bridge at the third floor level.

Several smaller scale projects were completed for the Cancer Research Center, Center for Materials Science and Engineering, and Mechanical Engineering.

HARMON E. BRAMMER

Planning Office

This year's *MIT Factbook* indicates that the total number of on-campus employees (faculty and staff) have increased from last year by 75 to 8,240. At the same time, the number of faculty decreased by 3 to 960, or 11.6 percent of the total number of employees, though the steady increase in the tenure rate continued reaching 75.2 percent. The undergraduate student population increased from last year by 71 to a total of 4,348. This number is significantly lower (by about 309 students) from five years ago, due in large part to our current housing policy. The number of graduate students has remained relatively stable at 5,061. Although 93 percent of the undergraduates live in MIT or affiliate housing, only 27 percent of graduate students do so. This is still well below the Institute's stated goal of 50 percent.

A substantial portion of the Planning Office efforts over this past year were designed to prepare for the Institute's needs over the coming 10 to 15 years. Our research, analysis, and planning efforts have addressed each of several key resource areas in specific ways.

CAPITAL PLANNING
An extensive inventory of potential capital projects, their projected costs, and their location on the campus was completed in both detailed and summary form. These documents will be updated annually in order to provide a comprehensive picture of those capital needs and their implications for land and financial resources over the next 10 to 15 year period.

LAND USE AND DEVELOPMENT PLANNING
Studies of the west campus and north campus areas were completed this year. Although these studies were primarily focused on the development potential and utilization of MIT land holdings, the west campus efforts also involved physical survey and title research initiatives to clarify long-standing ambiguities. Related planning for graduate student, faculty, and staff housing also continued. In addition, a land resource requirements analysis was prepared for the Real Estate Subcommittee of the Investment Committee.

TRANSPORTATION PLANNING
Continuing work begun last year, studies are underway to rationalize traffic patterns along the northern, southern, and western sections of the campus. These explore crucial access and circulation routes and will be used in cooperation with efforts undertaken on behalf of the Unviversity Park development project and in cooperation with the City of Cambridge to find reasonable solutions to this pressing community issue. New parking development regulations now under consideration by the City (in an effort to conform to EPA guidelines) will have a significant impact on MIT's ability to manage its parking resources effectively. As part of a broad-based institutional response, the Planning Office has undertaken a review of MIT's transportation master plan as well as a new study of bicycle use by students, faculty, and staff.

LANDSCAPE PLANNING
The City of Cambridge has initiated a redesign of the Massachusetts Avenue corridor, and Planning Office staff are working to ensure consistency with MIT requirements along the section from the Charles River to Central Square. Planning for the west campus/Vassar Street area also addresses issues of landscape, pedestrian and vehicular circulation, and service requirements in this highly visible section of the campus as does the design for a new plaza at the Main Street/Carleton Street entrance to the east campus. The office has also worked closely with other MIT departments and representatives of the Cambridgeport neighborhood in planning for the renovation and landscaping of Institute property at 350 Brookline Street. A graphical record of all plantings and landscaping materials in use at the Institute and incorporating a mapping reference system keyed to campus base maps maintained by the Planning Office has been requested and funding strategies are being explored. In addition, the office has requested the resources needed to complete the Landscape Master Plan for the campus.

FACILITIES PLANNING
With construction of the new Building 68 (Biology-related activities) underway, the Planning Office has continued its efforts in preparation of an academic facilities plan for the main campus. This includes pre-design work identifying the availability of space in Buildings 16 and 56 (to be vacated by the Biology Department), the space requirements of various Physics Department activities, and the related relocation options for certain current occupants of Building 20. Studies of the space needs of the School of Management and the School of Architecture and

Planning were prepared for senior management review, planning for a new science teaching center is under discussion, and the renovation and refurbishment of existing classrooms enters the fourth year of a ten-year implementation plan. The development of a program to meet the Sloan School's needs for classrooms and lecture halls continues, and the renovation of Building E56 to house elements of the Sloan School and the activities of the Dibner Institute and Burndy Library is nearing completion.

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. Site studies for new graduate student housing in the Sidney Street area have been completed, and the development of a comprehensive housing plan, focusing on the northwest area of the campus, has begun.

PLANNING FOR INDIVIDUALS WITH DISABILITIES

As part of its standing commitment to provide 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. An ADA Compliance Review Committee has been appointed by the Senior Vice President and is being supported by Planning Office staff.

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 participation in several consortia which make available comparative institutional data. This year the Institutional Research area was given responsibility for coordination and submission of surveys and other data requests sent to MIT. Members of the group have also remained active in the Educational Studies Working Group.

O. ROBERT SIMHA

Safety Office

During the year, significant changes were made to the Massachusetts Worker's Compensation Law. These changes provided for reductions in employee benefits, alternative forms of dispute resolution, and severe penalties for the filing of fraudulent claims. Within the Institute, the Restricted Duty Program continued to reduce overall lost work days.

EDUCATION AND TRAINING

During the year, a vigorous program was implemented to address the potential for injuries associated with the extensive use of video display terminals (VDT's). The Safety Office worked in conjunction with Environmental Medical Services (EMS) to publish guidelines on the use of VDT's, conduct seminars for supervisors and individual department members, and carry out specific surveys upon request.

In addition to the above, Safety Guidelines were developed to assist in the supervising of participants in the Undergraduate Research Opportunities Program; a review of the training of Campus Police Officers for response to hazardous materials incidents was initiated; and in response to the recent passage of the Americans with Disabilities Act (ADA), a committee was formed to review issues such as identification and correction of access barriers.

An electronic mail address has also been established enabling individuals to write in with questions or concerns about safety. At the present time, there are 105 individuals serving as departmental safety coordinators across the Institute.

HAZARDOUS MATERIALS

A new procedure is being developed by the Safety Office and EMS to more efficiently handle the annual Superfund Amendments and Reauthorization Act (SARA) inventory of hazardous materials. During the year, efforts also continued to remove underground storage tanks. Over the course of the year, four tanks were removed from the main campus, one from Haystack, and one from Lincoln Laboratory.

In spite of a 10 percent increase in chemical waste, the addition of a technical assistant ensured the removal of waste in a timely and efficient manner.

FIRE PROTECTION

The installation of automatic sprinklers is complete in Buildings 54 and E17/E18 and work continues in Building 10. The installation of a fire alarm system in the main group continues on schedule.

The Safety Office continues to monitor and attend public hearings regarding fire and building code changes and new legislation that might affect the Institute.

SAFETY AUDITS

The City of Cambridge, in conjunction with Kemper Insurance, continued to perform annual inspections of the campus.

The Occupational Safety and Health Administration (OSHA) conducted two departmental inspections this year as the result of written employee complaints. Although most of the alleged citations were not substantiated, a few code violations were cited. These were abated in the allotted time.

In order to assist the Dean's Office in implementing their program to encourage the independent living groups to install safety systems in their buildings, many MIT fraternities were inspected during the year.

JOHN M. FRESINA

VICE PRESIDENT AND SECRETARY OF THE CORPORATION

This section of my annual report is devoted to the exploration of Total Quality Management (TQM) as a leadership and management approach that has the promise to improve the effectiveness of our jobs and of the services we provide at MIT.

The Demand for TQM

The impetus for introducing TQM in my areas of responsibility came from three sources, concurrently: First, a persistent notion was voiced and discussed among the directors and senior staff in my areas--who constitute the Vice President's Staff Group (VPSG)--that we must learn to *do our jobs in different ways* in order to cope with complex future challenges and constraints, including demographic trends, federal cutbacks, heavy regulation, increased demand for human services, and budget problems. This notion developed as a result of the Vice President's Staff Group authoring a paper with our collective views of *The Issues and the Agenda for MIT in the 1990s*. This paper was submitted in December 1989 to the Corporation Committee on the Presidency and was published in my 1991 annual report.

What it means to "do things differently" was never defined. But one project, begun in 1991, to acquire and introduce a new personnel information system at MIT, was probably the best example of the *new* approach to our work that some of us had envisioned. Basically, this approach entailed the decision to purchase an established, state-of-the-art information system off the shelf. The new system involves a significant change both in software and hardware: The software consists of an integrated package of diverse capabilities each developed and supported by its vendor. The hardware requires a change from large mainframe technology to personal computer workstations linked into a local-area network. The idea of adapting our way of doing personnel paper work to an established new system was a major departure from MIT's past practice of developing our own new systems to fit current and historical business practices and procedures. There will be more to say on this project next year.

A second force that led us to TQM was the extensive urging and advice from several of our MIT trustees, who are top executives of companies that have made a major commitment to use TQM, and who feel that MIT would benefit significantly from adopting TQM both as part of our teaching programs and as a practice in our academic and our administrative operations.

The third impulse for TQM was our recent experience with our program, *Building on Differences* (1990 and 1991). Last fall we experienced skepticism and resistance to expanding this program beyond the first 135 volunteers who took the course out of a total of 650 people in my areas of responsibility.

The consistent feedback in the spring of 1991 was that *the ideas in the program were very valuable but "were neither recognized nor practiced in the MIT workplace."* We decided to take a breather from offering the program in 1991-92 until we could figure out how best to respond to the resistance and the skepticism of our colleagues. My prefatory remarks in this section of the Annual Report last year were devoted to my observations and reflections on this issue.

Exploratory Activities

Our first step in exploring how TQM might be useful in our areas of responsibility at MIT was to establish a task force of representatives from all of our departments, chaired by Bob Weatherall, Director of Career Services, to *study TQM literature* and to learn about experiences outside MIT. Concurrently, we arranged for visits by the Vice President for Quality from AT&T and by representatives from the University of Pennsylvania (winter and spring 1992), where TQM had already been introduced and tried reportedly with some success. We studied all of the information collected, and we assembled a library of TQM books, reports, and articles. Some of us attended industrial and business presentations about TQM throughout the year.

In addition, in the spring and summer months, I had extensive consultations with Deputy Dean Steven Graves of the Sloan School, Professor Thomas Lee (EECS Professor Emeritus and Director of the Center for Quality Management--a Boston-area consortium), and Visiting Professor of Management Shoji Shiba. Professor Shiba has been responsible for the introduction of TQM at the Sloan School and at a dozen leading high technology companies in the Boston area. These companies, in turn, have founded the Center for Quality Management (CQM).

At the suggestion of our consultants, we arranged for a special half-day workshop on June 10 to introduce TQM to the V.P. Staff Group, led by Michael Bradley, Director of Quality at Teradyne, Inc. This was followed by a more intensive three-day, custom-designed workshop on TQM concepts and techniques, conducted by Professor Shiba and attended by 20 staff members from our areas. This workshop was held under Center for Quality Management auspices at MIT on July 6, 9, and 30, 1992. In my opinion, this special workshop by Professor Shiba was by far the most effective introduction of TQM concepts.

There were other exploratory activities in the spring and summer as well: Kathryn Willmore, Director of Public Relations Services, organized a two-day workshop on July 21 and 22 to introduce the TQM Seven Steps and Tools (techniques) to the Public Relations staff. This program was conducted by Goal QPC (a consulting organization whose teaching materials have been used by other MIT areas) and was attended by some of the Shiba course attendees as well.

I signed up to attend an intensive course for senior executives offered by CQM in three two-day sessions during July, August, and September 1992. Finally, in late August, a few representatives from our areas, including the Director of Personnel, the Assistant Equal Opportunity Officer, and Assistant Directors from the Medical Department and the MIT Press, joined me in attending a special five-day course offered to 75 MIT attendees by IBM in order to introduce IBM's Market-Driven Quality Programs (the IBM version of TQM) to the Faculty in Management and Engineering.

All in all, last year's exposure to several introductory programs and the learning to date from these programs, and from the experiences in other organizations, have provided valuable insights as to the nature and the value of TQM concepts and methods and the ways in which we might adapt and custom-design such an approach for MIT.

The Promise of TQM for MIT

What is TQM? Professor Shiba describes TQM as "a thought revolution!" The gist of my own observations, from everything that I have learned so far, is that TQM is a systematic, common-sense approach to problem finding, problem solving, and the managing of work processes. The TQM approach is all-inclusive and integrative (in the sense of bringing together and weaving together perspectives and techniques), iterative toward continuous improvement, and demand (or market) driven; and, in my view, those are its three cardinal values. To elaborate:

- TQM concepts *bring together analytical and intuitive thinking*, both in identifying and in solving problems.

- TQM techniques *weave together different styles of thinking* through the development of common language and through highly disciplined group exercises. These exercises force dialogue (and engagement with the ideas of other people) and encourage both consensus (on key issues and priorities) and the existence of "lone wolf" ideas. The team exercises tend to stimulate and to marshal creativity rather than stifle it.

- TQM emphasizes *iterative efforts toward continuous improvement*, thus avoiding the one-time fix-it mentality that has often guided and has tended to dominate traditional problem-solving efforts.

- TQM insists on the *"voice of the customer"* (where "customer" is the recipient of a service or product or of any piece of work that passes hands from one person or group to another, within or across the boundaries of an organization). This insistence on the "customer" assures not only feedback on the quality of services provided, but also a means of including the customer perspective in the design of new products or services. (A method of product or service development called Concept Engineering was designed and completed by research within CQM in the past two years.)

Based on these observations, I do believe that--properly introduced and practiced at MIT--some form of TQM holds a promise to deliver powerful working tools that would help and motivate us to look at old problems and old ways of doing things with new perspectives and, indeed, help us to *"do things differently" in the interest of continuous improvement.*

I believe, as well, that the TQM approach, and specifically its mode of cross-functional teamwork, will give us the opportunity to further refine and to capitalize on the concepts and the skills developed in our program *Building on Differences*. This may represent a unique opportunity for us to contribute to the overall development of the TQM approach in the US. I say this because, to date, I believe that TQM principles and techniques have been hardest to apply in services that are people intensive and in the building of effective teams. In fact, at the time of this writing, we are in active dialogue with AT&T Quality staff who have approached us to find out more about the *Building on Differences* program and its possible application to improve quality initiatives.

There are some obvious obstacles to applying TQM notions in non-manufacturing settings where the output (a service to people or, worse yet,...education) is not a palpable product and where the meaning of the term *customer* is not readily understood or accepted. Who is the customer of the university? Is education or educated students the product? Are research sponsors customers? Faced with these very complex realities of the university as an institution (or of education as an *industry*) several educational institutions to date have approached TQM from a limited perspective, trying to introduce Quality Initiatives and techniques and processes that have worked in industry to the university's most industrial or business-like operations, such as purchasing or building services--mail or trash collection--and the like.

My conviction is that the advantages of TQM--what I call the total-involvement or the institution-wide integrative approach--are diminished if TQM is thought to apply only to limited areas of the university, i.e., those non-academic services or administrative operations that come closer to resembling industrial or business operations (for example, the book production process at the MIT Press, or the maintenance of the athletic fields, or the food service). My own interest in bringing TQM approaches to MIT is predicated on a large-scale acceptance of its applicability across both academic and administrative operations and services. The nature of many of the activities in our areas--such as admissions, physical education, and health care--cut across academic and non-academic areas and are, I believe, a good testing ground for TQM in its broadest scope.

Next Steps

It is clear to me that basic learning of TQM concepts and techniques will continue in the next few months, until we have a substantial base of managers and staff who understand the approach well enough to use it in our work.

Looking ahead, we are tentatively thinking of using explicit TQM techniques in the introduction of the new personnel system to the community during the winter of 1992-93. A Quality Improvement Team here may be composed of personnel and systems professionals as well as academic and administrative office users of the personnel system.

We also plan to launch this winter two or three other cross-functional team projects, drawing on existing or new problems/projects in our areas, as well as on people from several departments both from within our areas and from other faculty, staff, or student groups. The aim will be to tackle these

real problems, to gain more experience, and, as we become successful, to encourage expanding the approach to other areas. Examples from which to choose the first QI projects may include: (a) a new health benefit for retirees offered by the Medical Department (or by an outside HMO provider); (b) improved servicing of retirees (or prospective retirees), and expanded retirement plan options; (c) a more successful system of recruiting and retaining minorities throughout MIT; (d) an improved and cost-conscious Admissions publications plan; (e) improved and more intensive health and wellness courses for our student physical education program (the athletic graduation requirement); (f) a more effective program of MIT communications and public relations; and (g) the introduction of electronic publishing of scholarly work (books and journals).

To recall Professor Shiba's wise advice: We need to learn how to learn by doing, instead of expecting to learn first and then do.

CONSTANTINE B. SIMONIDES

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, 1992, the following members completed their designated terms of service: John K. Castle '63; Walter J. Humann '59; F. Richard Meyer, III '42; Rita A. O'Brien '77; and Robin M. Wagner '86.

Elections to Term Memberships

The following nine members were elected to the Corporation for five-year terms beginning July 1, 1992: Pedro Aspe Armella '78; Gerald J. Burnett '64; George N. Hatsopoulos '49; Robert B. Horton '71; Nannerl O. Keohane; William B. Lenoir '61; Robert M. Metcalfe '68; Dava J. Newman '89; and Romano Prodi. (Mr. Horton served a previous five-year term.)

Elections to Life Memberships

Shirley A. Jackson '68 and Frank Press were elected to Life Membership, effective July 1, 1992.

Ex Officio Members

In August, 1991, Harold Raynolds, Jr., who had served as Massachusetts Commissioner of Education since 1986, resigned this post, and in March, 1992, Robert V. Antonucci was named to succeed him. As Commissioner, Dr. Antonucci is an *ex officio* member of the Corporation in the category of Representative of the Commonwealth of Massachusetts.

On June 30, 1992, Peter M. Saint Germain '48 completed his term of service as President of the MIT Association of Alumni and Alumnae and was succeeded by Robert A. Muh '59.

Transfer to Emeritus Status

At the December 6 meeting of the Corporation, the Chairman noted that on November 3, 1991, Dr. Jerry McAfee '40 had reached the age of 75, and, in accordance with Section 5.1 of the Bylaws, was therefore transferred to the status of Life Member Emeritus. Dr. Gray commented on Dr. McAfee's outstanding service to the Institute and to the Corporation and welcomed him to the distinguished rank of Life Member Emeritus. To mark the occasion, Dr. McAfee was presented with an MIT wristwatch engraved with his name and his years of service as a Life Member.

A similar ceremony was held at the meeting of March 6, 1992, when Harold J. Muckley '39 was transferred to Life Member Emeritus, having reached his 75th birthday on February 17. Dr. Gray commended Mr. Muckley for his generosity to his alma mater and expressed his appreciation for Mr. Muckley's long and faithful service to the Corporation. Mr. Muckley was presented with an inscribed MIT wristwatch and received the warm applause of his colleagues.

Deaths

At the December 6 meeting of the Corporation, the Secretary presented memorial resolutions honoring Life Member Emeritus Robert C. Sprague '23 who died on September 27, 1991.

At the March 6 meeting of the Corporation, three sets of memorial resolutions were presented. Dr. Gray presented resolutions honoring Life Member Yaichi Ayukawa '52 who died on November 30, 1991. The Secretary presented memorial resolutions honoring Life Member Emeritus Frank R. Milliken '34 who

died on December 4, 1991. President Emeritus and Former Chairman Howard W. Johnson presented memorial resolutions honoring Life Member Edwin C. Whitehead, who died on February 2, 1992.

CORPORATION COMMITTEES

Executive Committee

This committee is chaired by the President and includes the Chairman of the Corporation and the Treasurer, *ex officio*, and seven elected members. In 1991-92 the elected members were W. Gerald Austen, Samuel W. Bodman, Edward E. David, Jr., Norman B. Leventhal, Raymond S. Stata, Morris Tanenbaum, and Mary Frances Wagley. I have served as Secretary of the committee since 1971. On June 30, 1992, Mr. Leventhal completed a two-year term on this committee, and Dr. Wagley completed a five-year term. At the Corporation meeting on June 1, Karen W. Arenson was elected to a two-year term, and Shirley A. Jackson was elected to a five-year term, both terms beginning July 1, 1992.

During the past year the Executive Committee held ten meetings. In addition to the regular agenda of monthly reports and deliberations on many issues pertaining to MIT policies and operations, the Executive Committee received in-depth reports on the antitrust litigation against MIT, initiated by the Department of Justice on May 22, 1991, on MIT's financial aid practices. Thane Scott, Esq., from the Boston firm of Palmer & Dodge, principal counsel to MIT on this case, and other advisors to the Institute, participated in some of the discussions. The case came to trial before Chief Judge Louis C. Bechtle in the Federal District Court in Philadelphia from June 25 to July 9, 1992. Judge Bechtle's judgment is expected sometime in early fall.

Throughout the year, the Executive Committee also received regular monthly briefings on the Defense Contract Audit Agency (DCAA) audits at MIT and on other developments related to the issues of indirect cost reimbursement (ICR) for the expenses of sponsored research.

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 1991-92 fiscal year under the chairmanship of Breene M. Kerr. Serving with Mr. Kerr this year were Michael M. Koerner, Norman B. Leventhal, Robert A. Muh, DuWayne J. Peterson, Jr., John S. Reed, and Richard P. Simmons. Mr. Leventhal and Mr. Peterson completed their terms on June 30, 1992. They will be succeeded by Charles H. Spaulding, who will serve a three-year term on this committee, and William J. Weisz, who will serve a two-year term. Mr. Muh was elected to a term of five years. Both the Chairman of the Corporation and the Treasurer serve as *ex officio* members. Allan S. Bufferd, Deputy Treasurer and Director of Investments, serves as Secretary of the committee.

The Wellington Management Company of Boston has continued as investment manager and advisor for publicly traded securities, both domestic and international. In addition, the program for domestic and international alternative investments to publicly traded securities was continued. These alternative investments, including venture capital and management buyouts, are typically managed by several investment managers through pooled investment funds.

Membership Committee

This committee is chaired by the Chairman of the Corporation, who also appoints its members. This year those serving with Dr. Gray were Angus N. MacDonald, Carl M. Mueller, Rita A. O'Brien, Morris Tanenbaum, and Edward O. Vetter. Ms. O'Brien completed her term on June 30, 1992, and was succeeded by Dolores Wharton. The President serves as an *ex officio* member, and I serve as Secretary of the committee.

The Membership Committee met three times during the academic year, in October, December, and March, for substantive discussions of membership matters. Throughout the year the committee members stayed in touch by telephone and mail to exchange recommendations and review

nominations. In his quarterly reports to the Corporation, Dr. Gray asked the members to continue sending suggestions and thanked them for their earlier responses.

Elections to membership on the Corporation are noted 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 in October.

Screening Committee
The Corporation Screening Committee to nominate recent graduates to membership on the Corporation was chaired this year by Robin M. Wagner. The other members of the committee were Edward H. Linde, Bernard Loyd, Jennifer L. Lund, and Megan J. Smith. As has been done for the past several years, an open meeting was held for students in November, 1991. In addition, Jennifer Lund prepared an article on the Corporation for *The Tech* to serve as a guide for recent alumni who might be interested in being nominated for Corporation membership.

The Committee met several times during the academic year 1991-92 and held two teleconferences, one in January and one in February. There were 59 candidates, from whom the committee selected 10 nominees for the ballot, 5 men and 5 women including 3 underrepresented minorities and 2 Asian-Americans. The ballot was sent to alumni who had received degrees in 1990 and 1991 and to candidates for degrees in 1992. Dava J. Newman '89 was the winner of this election, and her name was then presented to the full board by the Membership Committee as a nominee for a five-year term. As reported above, at the Corporation meeting on June 1, Dr. Newman was elected to a five-year term on the Corporation.

This year the Screening Committee also undertook a self-review to evaluate its effectiveness. The committee made specific recommendations to improve the process, and the Secretary passed these along to the Executive Vice President of the Alumni Association for implementation in the coming year.

Auditing Committee
The Auditing Committee was chaired again this year by Louis W. Cabot and included Denis A. Bovin, James A. Levitan, Jennifer L. Lund, and DuWayne J. Peterson, Jr., as members. There were two meetings, one on October 3, 1991, and one on March 5, 1992. At each of the meetings Auditing Committee members were joined by representatives of Coopers & Lybrand, the independent public accountants, as well as appropriate members of the MIT administration.

At the fall meeting the committee discussed the Financial Statement for the Year Ended June 30, 1991, 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, 1992. In addition, at each meeting the Auditing Committee was apprised of recent developments of the Defense Contract Audit Agency (DCAA) audits at MIT.

Advisory Committee on Shareholder Responsibility
D. Reid Weedon, Jr., continued as Chair, with Vice President and Treasurer Glenn P. Strehle serving as an *ex officio* member. The committee membership includes Senior Vice President William R. Dickson as well as Faculty and students. Elizabeth T. Harding provides staff support.

The committee met twice in the spring of 1992 and, in addition, conducted three telephone polls to vote on 62 shareholder resolutions from 38 companies whose stocks are held by MIT in its General Investments. The two most prominent issues were related to conducting business in South Africa (25 resolutions) and a new uniform code for corporate environmental reporting (16 resolutions).

Corporation Joint Advisory Committee on Institute-Wide Affairs
The Corporation Joint Advisory Committee on Institute-Wide Affairs (CJAC) held six meetings during 1991-92. Christian J. Matthew served his first year as Chair. Other Corporation members on the committee included Jerome H. Grossman, Jennifer L. Lund, Peter M. Saint Germain (*ex officio*), Emily V. Wade, and Harris Weinstein. Continuing a custom established during the last academic

year, postdoctoral representative Dr. Marcia M. Falconer was invited to attend meetings as a guest of the committee.

The recommendation made at CJAC's first meeting of the year -- to encourage academic departments to invite Visiting Committee members to attend undergraduate and graduate classes prior to the start of each committee's biennial meeting -- was implemented with great success.

Herman Feshbach, Institute Professor Emeritus and Chair of the Equal Opportunity Committee, briefed CJAC on initiatives underway to increase the numbers of underrepresented minority Faculty and women Faculty at MIT.

Associate Provost Samuel J. Keyser, Dean Frank E. Perkins, and Dean Arthur C. Smith reported on the reorganization in the administration of undergraduate education and academic support, and on sexual harassment at MIT.

Professor Ronald M. Latanision, Chair of the Council on Primary and Secondary Education, briefed CJAC on the work of the MIT Committee on K-12 Education and the Council on Primary and Secondary Education.

In December, Mr. Matthew met with the Executive Committee for the purpose of discussing the role of CJAC, and presented an oral report to the Corporation.

Following much discussion on ways to improve communication and increase interaction between students and Corporation members, a survey was designed and mailed to the Corporation to measure interest and availability on the part of members in participating in activities with students.

In November, CJAC members were invited to attend an annual dinner with the Corporation Screening Committee and student leaders, followed by an open meeting to discuss the functions of MIT trustees and the process by which recent graduates become candidates for membership on the Corporation.

At the last meeting of the year, Mrs. Wade, who was completing her term on this committee, was honored for her extraordinary service to CJAC, including six years as Chair.

Corporation Visiting Committees
During the academic year 1991-92, twelve Corporation Visiting Committees held meetings:

Fall 1991	**Visiting Committee**	**Chair**
October 28-29	Sponsored Research	Edward O. Vetter
November 21-22	Nuclear Engineering	Robert A. Charpie
November 25-26	Materials Science and Engineering	Edward O. Vetter
December 4-5	Civil Engineering	Frank S. Wyle

Spring 1992	**Visiting Committee**	**Chair**
February 5-6	Linguistics and Philosophy	Karen W. Arenson
February 18-19	Mathematics	Harris Weinstein
March 4-5	Mechanical Engineering	F. Richard Meyer, III
March 9-10	Athletics, Physical Education, and Recreation	Howard W. Johnson
April 1-2	Earth, Atmospheric, and Planetary Sciences	Breene M. Kerr
April 8-9	MIT Sloan School of Management	Robert B. Horton
April 29-30	Whitaker College	Angus N. MacDonald
May 3-5	Physics	David S. Saxon

In Edward Vetter's absence, Denis Bovin and Joseph Gavin served as Acting Chairs at the Sponsored Research Visiting Committee meeting.

All pending oral and written reports were completed for committees which had met in the academic year 1990-91. Oral and written reports were completed for committees which met in 1991-92 with the exception of three oral reports (Physics, MIT Sloan School, and Whitaker College) and four written reports (Mechanical Engineering, Physics, MIT Sloan School, and Whitaker College).

In 1991-92, 364 persons occupied 433 slots (131 filled by Corporation members, 162 filled by alumni nominees, and 140 by presidential nominees) on the Institute's 25 Corporation Visiting Committees. Membership included 19 percent women and 10 percent underrepresented minorities. Sixty percent of the members were affiliated with corporations; 32 percent with academia; 4 percent with foundations/arts; 4 percent with government. Three members resigned during the year: John L. Anderson (Chemical Engineering); Thomas R. Kuesel (Civil Engineering); and Peter R. Scanlon (Sloan School).

MEETINGS OF THE CORPORATION

Orientation Program

On October 3, 1991, the day preceding the Annual Meeting, an orientation program was held for new members of the Corporation. The program began with a luncheon at the President's House and an afternoon of presentations by the officers of the Corporation on the structure of the trustee body and an overview of the Institute by the President. Following the presentations and discussion, the new members were taken on a tour of the campus. At the end of the tour, the new members were joined by the members of the Executive and the Membership Committees for a dinner at the Faculty Club. As in the past, spouses of new members were invited to all the orientation events.

Annual Meeting

At the Annual Meeting on October 4, 1991, the agenda included Dr. Vest's first annual report as President. Dr. Vest said he had decided to use the opportunity his report provided to explore major issues now facing higher education and the research establishment in this country. He said he would also provide examples of MIT's responses to these fundamental issues. His text included comments on such issues as changing public attitudes toward the university/government partnership, the need to renew and review the Institute's commitment to academic integrity, and MIT as an international university in a technologically competitive world. A number of Corporation members participated in the lively discussion period that followed the President's remarks on these and other issues.

At this meeting the members also heard the annual report of the Auditing Committee and Mr. Strehle's annual report as Vice President and Treasurer. Reports were presented and approved for three Visiting Committees that held meetings in the spring of 1991, completing the oral reports to the Corporation on behalf of Visiting Committees that had met during the 1990-91 academic year.

At the luncheon that followed the business session, members of the Corporation and their spouses were joined by members of the Academic Council and their spouses. Massachusetts Governor William F. Weld, an *ex officio* member of the Corporation, also joined the luncheon, at which Life Member Harold J. Muckley and members of his family were guests of honor prior to the naming of the Dwight S. Muckley Building, described below under **Special Events**.

December Meeting

At the meeting of December 6, 1991, in addition to committee reports and reports from the President and the Vice President and Treasurer, the members heard a report from Dr. Walter E. Morrow, Jr., Director of Lincoln Laboratory. Dr. Morrow noted that Lincoln's mission over the years has been to develop technology for the Department of Defense (DOD) and other government agencies and, more recently, to give assistance to industry. These recent efforts involving interaction with industry have been undertaken with the encouragement of the DOD and Congress. Because of the declining DOD budget, it is clearly a period of transition for Lincoln Laboratory, but the Laboratory has been through periods of transition before and weathered them successfully. Dr. Morrow showed a series of slides giving an

overview of the kinds of projects currently being worked on at the Laboratory. It was an excellent presentation which drew a number of comments and questions from the members.

In response to a suggestion made earlier in the year by Corporation Member Richard P. Simmons, President Vest opened the floor at the December 6 meeting for a discussion by the members of concerns associated with the level of financial assistance now required to support international students at MIT. Many members of the Corporation participated in an extended and substantive discussion of these concerns, and several of them suggested that a committee be appointed to examine this complicated issue. (See report on meeting of June 1, 1992.)

In the afternoon, following the luncheon, guided tours of the newly renovated Rotch Library were available for members of the Corporation, and several members took advantage of the opportunity to see this much-admired facility.

March Meeting

At the meeting on March 6, 1992, before beginning his own report, President Vest invited Dr. Frank Press to speak to the members about the plight of the Russian scientific community following the dissolution of the Soviet Union. (Dr. Press, President of the National Academy of Sciences, had recently been asked to assist in putting together a group of advisors to aid President Bush in deciding what policies the U.S. should adopt with regard to Russian scientists who had been cast adrift in the present political situation.) Dr. Press's remarks elicited a number of comments and questions from the members who agreed that this was an important national issue that must be addressed.

At the March meeting, and at each quarterly meeting in 1991-92, President Vest commented on the status of the Justice Department's suit against MIT alleging violations of the Sherman Antitrust Act because for many years the Institute openly shared with Ivy League schools financial information given by applicants for aid who were common to more than one institution in the group.

At each Corporation meeting of the 1991-92 academic year, the President also commented on the status of the continuing audit by the Defense Contract Audit Agency (DCAA) with regard to the recovery of indirect costs for research. The President's comments on these topics always brought forth a number of questions from the members who followed both situations with much interest.

At the luncheon following the business session, past presidents of the MIT Association of Alumni and Alumnae were honored by the Corporation. Seventeen of them attended, and following the luncheon they gathered for a group photograph with Chairman Gray, President Vest, and William J. Hecht, the Executive Vice President of the Association. Later in the day the Association held a reception in honor of their past presidents and accompanying spouses.

Commencement Meeting

The Corporation held a breakfast meeting prior to the Commencement exercises on Monday, June 1, 1992. As is customary at this meeting, new Term and Life Members were elected (see above), and Commencement degrees were voted. Chairman Gray announced that, in response to the recommendation received at the December meeting of the board (see above), a committee on international students was being formed, the members to be appointed by the President and the Chair of the Faculty. Professor Sheila E. Widnall, Associate Provost, will chair the committee, whose membership will include two Corporation members, Michael M. Koerner '49 and Richard P. Simmons '53. The committee will focus on a whole range of questions relating to international students, including the question of a differential tuition, which had been discussed at the meeting of the Corporation in December.

At this closing meeting of the academic year, the Vice President and Treasurer gave his last interim report to the Corporation on the *Campaign for the future*. He was pleased to report that a total of $684 million had been raised to date, with just $16 million needed to reach the stated goal of $700 million. The Corporation is looking forward to Mr. Strehle's final report in the fall.

In his quarterly report to the Corporation, President Vest had much to report in the area of federal relations. He talked about increasing interaction between MIT Faculty and administrative staff and

members of the Congress and their staffs. In particular, he mentioned meetings in May that Associate Provost Sheila E. Widnall had held with Congressional staffers on issues such as academic responsibility and technology transfer. He expressed his satisfaction that an important opening event to launch the federal government's new National Technology Initiative had been held on the MIT campus. In addition, he reported that the first of a series of hearings across the country by the President's Council of Advisors on Science and Technology (PCAST) on the future of the American research university will also be held on the MIT campus. Such events do much to enhance MIT's visibility and communication with leaders in Washington.

President Vest also noted that two of MIT's former presidents received distinguished awards this spring. Dr. Jerome B. Wiesner received the Vannevar Bush Award from the National Science Foundation, and Dr. Paul E. Gray received the Imperial Decoration, Grand Cordon of the Order of the Sacred Treasure, from the Government of Japan.

SPECIAL EVENTS

Naming of Dwight S. Muckley Building

On Friday, October 4, 1991, following the Annual Meeting of the Corporation, in a ceremony that a number of Corporation members attended, Building E40 at One Amherst Street was named in honor of Dwight S. Muckley, the father of Life Member Harold J. Muckley '39. Present for the ceremony were Harold and Elizabeth Muckley, their three daughters and their son, as well as Mr. Muckley's brother and his niece.

The events were enlivened by a characteristic MIT hack, which was discovered a few hours before the ceremony. Someone had prepared a good-humored mock plaque for the dedication of "The E. Phortey Building," which drew laughter and applause from the assembled guests.

Dr. Vest noted in his remarks that the Dwight S. Muckley Building houses the most diverse collection of academic activities of any building on campus. The Corporation Resolutions, which Dr. Gray read at the dedication ceremony, noted that the Muckley Building "will serve as an enduring symbol of the bonds of friendship that exist between this distinguished Texas family and the Massachusetts Institute of Technology."

CONSTANTINE B. SIMONIDES

Admissions Office

For the third year in a row, colleges and universities across the country experienced declines in applications and yields (the proportion of admitted students who enroll). The combined effects of the recession, cuts in financial aid, and the decline in the number of college age students left many colleges with serious problems of underenrollment. To take one area, the Washington Post reported that most D.C. area colleges received 11 to 50 percent fewer applications in 1992 than they did in 1988. The university of Maryland-College Park dropped 19%, Howard 32% and Georgetown 11%. Colleges have had to admit a higher proportion of their applicants to fill classes. The percent accepted at the University of Virginia has risen from 28 to 35 at Georgetown. The yield has dropped from 32 to 26 percent at Johns Hopkins, and from 53 to 48 at Georgetown. These institutions, however, are still filling their classes with well qualified students. Schools further down in the "pecking order" have had to increasingly resort to tuition discounts, merit aid and loan forgiveness programs in order to fill the classes.

The experience has been somewhat different at the most prestigious institutions. In 1990, most experienced declines, but last year and this have held steady or have had modest increases in applications increased in both numbers (+3%) and quality. This was entirely due to changes in the pool of female applicants. We hope this was due to our two year effort to recruit high ability women. We admitted more students in order to enroll a somewhat larger class than in recent years. At this point, it appears that the class will number about 1125.

Last year marked the first time students who self identify as U.S. citizens or permanent residents and as "Caucasian or other" made up a minority (49%) of the entering class. That cohort declined again to 48%. We had a successful year with all minority groups except for African-Americans. The pool was similar in size, but not as strong as usual academically. We were not able to admit as many as in past years, and then we had a poor yield from those we did admit. Harvard had a similar experience with their African-American applicants, and we both found that our admitted students were accepting very large merit awards at other schools. We have to monitor this situation very carefully. On a happier note, although the yield among the very strong women we recruited was not what we had hoped for, we still enrolled the highest number of women in MIT's history.

We had a bit more success this year in enlisting faculty involvement in the evaluation process. The number of faculty members participating returned from 25 last year to the 1990 total of 40. Unfortunately, only 13 read more than 30 applications.

ADMISSIONS FOLDER READINGS
(# read by category of reader)

	88/89	89/90	90/91	91/92
Admissions Officer	9200	8900	8700	9100
Faculty	530	1000	700	890
Administrative Staff	2800	1900	3000	2400

We made a great deal of progress in the development of a new generation of communication vehicles. Our goal has been to maximize creativity and actually meeting the information needs of students while reducing costs. Our new video is nearing completion and will be ready for fall travel season. We are ready to move forward on the design and production of a new Viewbook and Search piece. We have completed the redesign of the freshman application, the Questions Brochure, the Central Meeting invitation and letterhead, the Profile, the transfer application and the international pre-lim application. We have created a new MIT Fact Sheet, an international students' brochure, a follow-up publication called "Insight" and are working toward completing a new Diversity Brochure to be used in recruiting minority students.

Our Student Ambassador's program ran very smoothly this year. Nine students spent time during spring break visiting high schools with large numbers of minority students. We hope to add six more minority student travelers next year as well as four non-minority students. We are also moving forward in the development of an MIT Alumni/ae Ambassador's Program which will enlist our minority graduates in the effort to bring more minority students to MIT.

We spent a lot of time working out the bugs in last year's major revision of all files and production programs associated with the database and in developing new reports. No serious problems were encountered, and we now have a more efficient and less costly system.

We followed through on our plan to move more of our fall travel to the spring. Having met with mixed results, we will return to a more modest effort in the spring.

We were again able to notify transfer applicants earlier and to guarantee them housing. Applications fell slightly, due, we think, to more careful screening of preliminary applications. We admitted 7 of 23 applicants for February, and 5 enrolled. For September, we admitted 70 our of 317 applicants and expect 40-45 to enroll. The vast majority of our transfer applicants continue to be either international students or Course 6 majors or both. Limitations on both those populations continue to keep transfer numbers low.

We have had a more dramatic decline in the number of special student applicants. These applications have been dropping for ten years, but especially in the last two. This is probably due to the recession as many special students have been company sponsored. Perhaps this area needs some attention in order to identify areas of potential growth.

602 students sought advanced standing and 514 received it.

We arranged for 407 overnights by visiting applicants.

The number of applications from international students continues to grow (from 857 in 1989 to 1162 in 1992). The process for handling the interest in MIT from abroad came close to collapse this year. We are working on solving this problem within our present staffing and budget levels, but may have to request help for this area.

CUAFA's directive of three years ago that we admit students with interests more in keeping with MIT's traditional strengths appears to be taking hold. Twenty sophomores in the class of 1995 declared HASS majors compared to 64 in the Class of 1993 and 28 in 1994.

Michael C. Behnke

ADMISSIONS TRENDS 1983 - 92

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Entrants from Secondary Schools										
Preliminary applications	12,653	12,465	14,698	14,349	16,237	17,408	17,832	17,941	20,169	17,423
Final applications	5,959	6,055	5,747	6,213	7,372	7,437	6,698	6,426	6,481	6,652
Admissions offered	1,818	1,854	1,885	1,762	1,826	1,833	2,018	2,051	2,012	2,219
Actual registration to date	1,082	1,059	1,061	991	1,001	992	1,045	1,084	1,049	1,157
Registrations as percent of admissions	61.1%	57.1%	56.2%	56.2%	54.8%	54.1%	51.2%	52.9%	52.1%	52.1%
Number of secondary schools represented	891	722	860	830	848	844	867	867	852	896
Percent of students from 9 northeastern states	50.5%	50.5%	44.7%	43.5%	39.8%	36.4%	32.5%	36.9%	37.1%	36%
College Transfers										
Total applications	1,024	1,048	909	890	870	905	688	838	839	792
Applications completed	400	304	295	317	304	349	328	399	389	339
Admissions offered	128	124	131	137	106	141	103	118	91	77
Actual registrations	91	91	101	97	80	94	79	98	77	54
Registration as percent of admissions	71%	73%	77%	71%	69%	69%	77%	83%	84%	70%
Graduate Students										
Total applications	8,836	7,922	8,032	8,564	8,443	8,863	8,655	9,445	10,002	10,714
Admissions offered	3,007	2,223	2,467	2,457	2,243	2,101	2,549	2,378	2,338	2,359
Actual registrations	1,542	1,290	1,338	1,105	1,019	1,104	1,437	1,169	1,179	1,211
Registration as percent of admissions	51%	58%	54%	49%	45%	53%	56%	49%	50%	51%

*expected to register; -actual number is not available

The Educational Council included 1661 alumni/ae this past year, representing MIT in all 50 states, the District of Columbia, Puerto Rico, The Virgin Islands, and 44 foreign countries. This group included 298 women and 69 minorities (46 Blacks, 5 Puerto Ricans, and 18 Mexican-Americans). The Educational Counselors represented MIT at 264 local College Fair programs; they conducted 6671 admissions interviews, and held countless conversations with prospective MIT students and with local school personnel. Of all MIT applicants, 94.2 percent (97.6 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 446 students, representing 123 different geographic areas (including 12 foreign countries), participated in this program run by the Educational Council Office.

Meetings for newly admitted students were held in 36 cities throughout the United States by Educational Council groups. Twenty-seven 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 and this past spring. Local Educational Council members assisted members of the Admissions staff in arranging for 96 Central Meetings in 88 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 90 volunteers, all women professionals (from AMITA, SWE, AWIS, AWM, or other women's professional organizations) to make 41 visits to 36 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.

The (somewhat out of date) MIT admissions videotape continues to be a popular medium. Requests for the tape came from 50 high schools, 11 Educational Counselors, 28 prospective students, and 6 MIT offices. (A new videotape is being developed by the Admissions office and will be available this fall.)

The MIT Alumni Award program is in its second year. The award, given to high school juniors for outstanding achievements, especially in areas of math and science, was sponsored by five alumni (all Educational Counselors) this year. MIT alumni/ae and/or MIT Alumni Clubs can sponsor an award for $25. The award winners receive a certificate in a leather MIT case and a year's subscription to *Technology Review*. Nine awards were presented this year.

Vincent James was appointed Director in September. A member of the Class of 1978, Vincent came to MIT after serving as a Systems Leader for a major New York bank.

VINCENT W. JAMES

I. OVERVIEW

The academic year 1991-92 for the MIT Department of Athletics can be viewed as one of completion, transition, and continued significant progress. Completion and transition refer, of course, to the fact that this is my final report as MIT Director of Athletics, Physical Education and Recreation after twelve years of service. As this report is being written, the final successor candidates are being interviewed by the search committee.

As the Department prepares for a smooth transition I note with a strong sense of pride the growth and accomplishments of our student-athletes, coaches, and administrators over the past 12 years. This pride is mixed with considerable gratitude in the knowledge that MIT has preserved and enhanced the crucial but fragile balance of strong academic commitment and competitive athletic opportunity with a sustained striving for excellence in both pursuits. Looking ahead, I am pleased to emphasize the many existing strengths and positive trends solidly in place for the new Department administration to build upon.

II. EXISTING STRENGTHS AND POSITIVE TRENDS

Intercollegiate competitive success enjoyed a significant resurgence in 1991-92 for both men's and women's programs with a combined win-loss percentage of .526 vs. .487 and .469 for the two previous years. Both men and women were above .500 for the first time in many years with several programs enjoying unprecedented success (see Exhibit V). Nine students in four different sports won a total of fourteen All-American honors while an additional twelve students in seven different sports won a total of 14 Academic All-American honors. Three MIT students won NCAA Postgraduate Scholarships while Rodrigo Rubiano '92 was named one of sixteen football players in the country to win a National Football Foundation & Hall of Fame Scholar-Athlete Award and Lisa Arel '92 was selected as senior gymnast of the year by the National Collegiate Gymnastics Coaches Association.

Consistent with such strong student success, five MIT coaches were named for a regional coach-of-the-year honor - a record level of coaching accomplishment for MIT. Our MIT intercollegiate coaches and instructors have been a superior group of men and women at MIT long before I arrived, and will continue to be long after I depart. Their versatility, hard work, and commitment to all MIT students is as fundamental to our educational success as any single component of our Department's structure. The breadth of our programs, the considerable spectrum of student achievement and the generally recognized national reputation we enjoy is due primarily to our dedicated and talented teaching and coaching faculty. Several of our coaches also assume major responsibilities for facility management in addition to their

coaching and teaching duties. I have enormous respect for the coaches-teachers-leaders of our dept and I offer them to the new administration with a deep sense of satisfaction in their effectiveness with students and in their well deserved reputation for fulfilling our mission the right way and the best way.

With the successful additions of intercollegiate women's lacrosse and women's track & field and the on-going formation and management of the numerous leagues/conferences with which MIT is aligned, the MIT intercollegiate program is able to provide our students with the broadest and most flexible opportunities for equitable challenge and competitive success consistent with our mission.

In the past decade we have added seven intercollegiate programs and expanded our conference affiliations always with the consistent objective of carefully controlling and shaping the competitive guidelines and athletic environment in which our students compete. Our intent is to ensure our MIT students a stable and positive athletic experience and we are pleased with our current framework of intercollegiate alliances. We believe this framework puts us in a favorable position to uncover and address any emerging issues that could threaten our delicate competitive balance.

Physical Education registration levels reached an all time high for the sixth consecutive year with an eight percent increase to 9,014. The increase came primarily from non-credit registrations, with step aerobics a significant contributor. Graduate student registrations also hit a new high to 1863. Several recently added programs solidified their appeal and bode well for the future, including boxing, the ropes-adventure course, and the MIT Wellness Equation for individualized health fitness awareness and responsibility.

The MIT Intramural Program has a well deserved national reputation for its broad based, student-managed activities that involve well over 50 percent of the undergraduate student body and an increasing percentage of graduate students. For all 12 years of my tenure, this vital program has been managed in a conscientious and caring style by Dave Michael. Dave is a consummate professional who knows what to do and does it with minimal fanfare. He has been a rock of support and friendship for many students over the years and certainly for our Department and for me.

Strong support for future facility needs has been provided by the Department of Athletics Corporation Visiting Committee and by the senior administration of the Institute. The successful completion and acceptance of the feasibility study for the three-stage Central Athletic Facility included "enthusiastic support" from the 1992 Visiting Committee and consensus of the MIT Senior Administration with respect to collaboration on project fundraising requirements and the projected timetables for beginning and completion of construction. The ideal scenario would lead to final project completion of the third stage by 1999.

During the 1991-92 year several key athletic facilities were upgraded including the squash courts in the Alumni Pool, new dugouts for baseball and softball, crack-patching of Steinbrenner Track and agreement with Physical Plant on a complete upgrade of the MIT outdoor

playing fields beginning this summer with Steinbrenner Stadium Oval. This field upgrade project will include the upgrade of Area C practice field to a vastly improved competitive intercollegiate surface to be renamed the Mr. and Mrs. Maurice Katz '42 Field in honor of the MIT alumnus who made this project possible with a $150,000 gift.

Note - a complete list of MIT Athletic Facility future needs is included in this report as Exhibit VI. As this report is being written, there have been requests from Vice President Simonides to Senior Vice President Dickson to proceed this summer with the planned press box for Steinbrenner Stadium, the Dupont Outdoor Tennis Complex resurfacing project, and the feasibility study for expansion of Pierce Boathouse to be financed by the Friends of MIT Crew.

The General Department Agreement for the hiring and promotion criteria under the Allen-Flippin Faculty Restructuring Plan is the culmination of several years of collaboration and discussion to establish our department teaching/coaching staff as continuing full-fledged members of the MIT Faculty without the specific designation of tenure. The new administration of the Department will have the Allen-Flippin Plan framework in place and the benefit of my specific recommendations to Vice President Simonides with respect to individual titles and future promotion timetables.

As we prepare for transition, a new administration will inherit a Department of superior ability, commitment, and positive spirit with several strong-performing individuals ready for more responsibility and all prepared to serve, learn, and develop with thoughtful attitudes and collaborative instincts. This is generally true for full-time and part-time colleagues alike. We have numerous examples:

- There is general agreement that our clerical support staff under the leadership of Sandy Lett and Laura Capone has never been so competent, flexible and congenial according to many long-term Department colleagues.

- We are grateful for the constructive and effective manner in which Rod Arthur, his athletic utility staff and the Operations Assessment Committee consolidated the Operations Unit following Bill Malone's retirement.

- With all the discussions involving the Allen-Flippin Faculty Restructure Plan we would make special mention of the patience and dedication displayed over many months by the Gang of 5 (expanded to the Gang of 7) in developing a consensus on hiring and promotion criteria for implementation of The Plan.

- The senior physical education management team of Director Gordon Kelly and Assistant Director Candy Royer deserve very special mention for their fervent and continuous quest for enhanced program excellence and increased participation in this crucial cornerstone component of our Department. Record levels of registration, a broader program offering both during the academic year and the summer period, and full resolution of the once traumatic "senior graduation crisis" are but three examples of this vital and energetic group.

- The relentless cooperation and quiet leadership of Assistant Director Fran O'Brien has been invaluable to this Department in so many ways. Somehow he continues to coach two seasons of baseball - fall and spring - while managing both our club and intercollegiate programs to increased levels of breadth, participation and student satisfaction.

- Paul Grace, Director of Sports Medicine and Equipment and Roger Crosley, Director of Sports Information are two professionals of intelligence, energy, and ability who have always cared for and managed beyond their required duties to the benefit of this Department. They both share their knowledge with the broader MIT Community in unselfish and effective ways typical of their dedication and affection for MIT. Their areas of responsibility reflect this attitude. Their potential for leadership and contribution will always be significant.

- Associate Director Jane Betts preceded me at MIT by several years and has always provided me and our Department with extraordinary leadership, insight, and counsel while handling at one time or another most of the major administrative responsibilities of the Department. She has been a tower of strength both internally and nationally for MIT and for intercollegiate athletics.

- The MIT Athletic Board of faculty, administrators, alumni, and students has been a precious vehicle of dialogue, advice, and counsel for our Department and for MIT. Professor Jim Mar chaired the search committee that brought me to MIT and served as my first faculty chairperson. Professor Tom Allen has been the Athletic Board Chairperson for the past several years and chairs the search committee for my successor. I cannot imagine two more effective leaders for MIT than these two men. I am forever grateful for their wisdom and inspiration through all the usual ups and downs of a twelve year administration.

In addition to the Faculty Chairperson and our own Department staff four other MIT colleagues have served on the MIT Athletic Board for all twelve years of my tenure. Their presence and contributions have been enormously valuable to me and to MIT Athletics. I mention them by name with respect and affection:

- William Reynolds - Alumni Representative
- Robert Simha - Director of Planning
- Constantine Simonides - Vice President
- Arthur Smith - Dean of Student Affairs and Undergraduate Education

III. THE FINAL LOOK

Throughout my tenure as MIT Director of Athletics, there have been two constants most influential and crucial to our progress. One is the students of MIT and the other is our Vice President, Constantine Simonides. Both have been unfailing believers in our value to the MIT Community and both have been singular in their dedication to our support and concern for our needs. I cannot imagine a more deserving or endearing "ultimate consumer" than the MIT students over the years

who have served in every possible role as advisors, leaders, and personal friends in addition to their performances on our various intercollegiate, intramural and club teams; MIT Athletic Association, Intramural Association and Varsity Club; our MIT Athletic Board, security force and equipment desk. There can not be a finer assemblage of college students in this country and I am grateful for our association and the privilege of serving them.

By the same token, I cannot imagine a more creative and thoughtful leader of gentle support and constructive guidance than the Vice President I have had the special honor of reporting to for all twelve years of my tenure - Constantine Simonides. The experience of serving MIT as Director of Athletics has enriched my life immeasurably and Constantine initially made it all possible by believing in my candidacy, appointing me, and staying with me and for me every step of the way. If things have gone well enough I am happiest for my friend and leader, Constantine Simonides. Thank you for the most satisfying twelve years of my professional life.

Royce N. Flippin, Jr.

Career Services and Preprofessional Advising

For the second year in a row the economic climate was not promising for graduating students entering the job market, or for students looking for summer jobs. The number of employers recruiting at the Careers Office barely matched last year's figure, which was down 20 percent from 1989-90. The last three years have seen the recruiting picture change as follows:

	1989-90	1990-91	1991-92
Employers coming recruiting			
Private companies & non-profit organizations	457	363	359
Government agencies	20	19	12
Number of students having interviews			
Undergraduates	970	769	971
Master's & Engineer degree candidates	342	380	357
PhD & ScD candidates	212	262	289
Total number of interviews	10,400	9,144	8,825

Not only have fewer employers come recruiting but they have sent smaller recruiting teams, reducing the number of students they were prepared to see. Nevertheless, as in previous recession years, MIT candidates generally have fared remarkably well. This is especially true of students in engineering and management. They have continued to land good summer jobs and good jobs at graduation. And they have continued to be discriminating in the jobs they go after. While many employers' interview schedules were oversubscribed this year, other employers could have seen more students.

MIT students are resourceful as well as bright and this no doubt accounts in large part for their success, but it is worth noting other factors working in their favor. The first is a clear disposition on the part of many employers to target their reduced recruiting efforts at quality schools. They are applying TQM principles to their recruiting as to their other sourcing.

A second factor is the strong demand almost everywhere in the economy for individuals who like working with computers and can make them perform. MIT students have this ability in spades, almost irrespective of major. We have asked the June class to specify the kind of work they will be doing to see how many are involved with software. We are guessing that it will be a considerable number.

Finally, Wall Street has recovered from the debacle of 1987 with a vigorous appetite for individuals who can understand the mathematics of options, futures, swaps, etc. It has realized that MIT students are a rich source of this talent and has come after them aggressively. They, in turn, have responded eagerly. Demand has also come from management consulting firms of one sort and another. Sixty-six of the 359 private companies counted above were in one or the other of these two categories and were responsible for an equal share of the interviews counted (1,615 out of the 8,825 total). It is quite likely that students from the main campus taking jobs on Wall Street and with management consulting firms this year will outnumber those from Sloan.

The recession showed itself in salary offers, which moved up in most cases at less than the inflation rate. Students enjoying the largest gains were bachelors in chemical engineering, who received offers 7 percent higher than last year, masters in mechanical engineering who received offers nearly 8 percent higher, and PhDs in electrical engineering who found industry willing to make offers 15 percent higher. The median industrial offer to bachelors in chemical engineering was $41,100. The median for bachelors in electrical engineering (Course 6-1) was $37,000, in computer science (Course 6-3) $36,000, in mechanical engineering $37,800, and in management $35,000. The median offer to masters in mechanical engineering was $43,300. The median for masters in electrical engineering, and also in computer science, was $43,000.

Students in other disciplines have felt the bite more sharply. It was another difficult year for graduates in architecture and urban studies. Others who have found the market extremely tight are PhDs in physics and mathematics hoping for jobs in academia. A number of them have been attracted to the opportunities for mathmaticians (and others with advanced mathematical skills) on Wall Street. It has also not been an easy time for international students who would like to work in this country before returning home. Many have borrowed dollars to support themselves at MIT and need to earn a good salary in a hard currency to repay their debt. In a particularly anomalous position are students from the People's Republic of China - many of them PhDs - who, since Tienanmen Square, have been allowed to prolong their stays in this country but have not been granted permanent visas. International students constitute a significant portion of our client population.

Medical School

The year saw a rise in the number of MIT applicants to medical school, paralleling a rise in the nation at large. Our preliminary data show 131 MIT candidates, up from 119 at the same time last year. They include 91 undergraduates, 2 graduate students, and 38 alumni. Forty-four of the undergraduates are women- very nearly half; the graduate student and alumni candidates are divided exactly (20, 20) between men and women. There was the same equal balance in the applicant group in 1991, when 83 percent of the women were accepted and 77 percent of the men. We would like to see an equally high acceptance rate this year but the increasing number of candidates nationally lengthens the odds a bit. We still expect a very creditable showing.

ROBERT K. WEATHERALL

Medical Department

INTRODUCTION

The MIT Medical Department is not insulated from the multitude of problems that beset the health care profession and industry. Our smallness is both a blessing and an added burden. We continue to place patient needs first. That requires us to provide low barriers, choose the most able health care providers to work here, encourage mechanisms for prompt and clear communications, facilitate access to tertiary consultants and technologies, make preventive and educational efforts available and effective, and do all this in a lean financial environment.

This has been a year in which many of the above objectives have been met, but not completely. We continue to examine ways of improving communication, be more responsive to criticism, expand access for our student body, develop programs for care of our growing senior citizen patients, bring costly technologies under control, bring certain tests within the Department and use our Inpatient facility even more effectively and efficiently.

In the current climate of health cost containment, our dependency on outside facilities and personnel makes our task more difficult. In the current climate of consumer unrest and frustration with the system we are also exposed to those pressures as well. Hopefully, this report will clarify our continuing vigilance in many areas requiring our wisest efforts to do well for our patients and be fiscally responsible.

MEDICAL CARE ACTIVITIES

Dental Service: Cynthia Stevens, D.D.S., Chief

The Dental Service is currently engaged in an internal and external evaluation of the practice, its place within the Department and the needs of the Institute. The financial structure and management practices, the scope of services provided, the special needs of students and decisions about expansion or contraction of services constitute major themes in study and in discussion.

Medical Service: Walter T. Rymzo, Jr., M.D., Chief

In July 1991 the leadership baton was passed from H. Walter Jones, M.D. to Walter T. Rymzo, M.D., In retirement from practice Dr. Jones continues to serve the Department as a senior advisor and the Institute as Chairman of the Committee on the Use of Humans as Experimental Subjects (COUHES). The pace of change, modifications and improvements, has perhaps even quickened during this past year. Appointments scheduling has been improved both at the Front Desk and through physicians' secretaries. Voice mail is utilized for routine after hours calls and a cellular telephone is now carried by the internist on call for the inpatient unit, an appropriate use of modern technology to enhance immediate communication. Exercise stress testing has been brought in-house, supervised by Dr. Rymzo. We have contracted with Dr. James McFarland and Dr. Irene Kuter of the Massachusetts General Hospital (MGH) to provide tertiary consultation in cardiology and oncology respectively. Access to a woman oncologist expert in breast cancer therapy has been a strong request from Health Plan members.

Primary care internists have been meeting monthly to discuss and plan implementation of a number of other projects important to patient care and physician education. Included in these efforts are improved methods of communication to backup physicians, a pharmacy direct phone line, the implementation of pain management education and procedures in the inpatient unit, optimizing access of students to the Department, training in advanced life support (in conjunction with Harvard University Health Service), planning for a core library and implementing computerized medical literature search data bases for rapid availability by physicians.

Two new committees were formed, one to review the role of nurse practitioners within the Department, the other to examine utility of various so-called routine examinations and laboratory procedures. As a reflection of our desire to learn from each other, the primary care physicians meet twice monthly to discuss ambulatory care problems seen in practice and an additional session is planned with the primary nurse practitioner group.

Sessions providing continuing medical education credits (required for licensure) are held once or twice monthly in the Department and our group also attends Grand Rounds at the MGH or Mount Auburn Hospital. We are actively involved in the education of students in the combined Harvard-MIT medical program (HST) as well as with the Medical Engineering Medical Physicals group (MEMP). Dr. John M. Moses retired from active practice in December 1991, but has continued to provide leadership in two courses for HST students, the first year

INTRODUCTION TO THE PROFESSION and the second year REAL MEDICINE course. He also continues to serve the Institute with distinction as Chairman of the Animal Care Committee. The Medical Service sponsors a monthly subspecialty conference and many individuals take on the responsibilities of being pre-medical advisor for a cluster of MIT undergraduates.

Off Hours Service: Leigh M. Firn, M.D., Coordinator
Over the past twelve months there have been no significant changes in the operation of the After Hours Service. Emergency care continues to be provided on a 24-hour basis by a combination of nurse practitioners, staff internists, and moonlighting physicians drawn from fellows at various teaching hospitals in the greater Boston area. Primary care residents from the Mount Auburn Hospital doing ambulatory rotations at the Medical Department help to provide weekend coverage. Patient volume remains high. There were about 7,500 visits last year, an increase of approximately 5% over the previous year. To cope with the increased load during peak weekend hours, we have added a medical assistant to our staff. We have also updated some of our emergency equipment and plan continued medical education with the staff in cardiac life support.

Inpatient Medical Service: Elaine L. Shiang, M.D., Chief
The flagship of the Medical Department, the Inpatient Unit, had over one thousand admissions this year. Infections included measles, chicken pox, infectious mono, urinary , gastrointestinal and respiratory problems. We also cared for patients with malaria, typhoid fever, AIDS, skin infections, various cancers and a variety of other challenging medical and surgical problems.

The Clinical Research Center (CRC) recently received a four year renewal grant which may result in even greater numbers of study patients than the approximately 350 admitted this year. These patients are on 12-24 hour protocols, or may be part of long term studies of Alzheimer's disease and other chronic nervous system problems. Interactions between CRC staff and the inpatient nursing and medical staff have been increased as part of the overall effort to care for CRC patients in our Unit.

We have successfully developed the capability of providing inpatients and ambulatory individuals blood transfusions through a cooperative venture with Cambridge Hospital. Committees in place are continuing to study and advise the Department on a range of issues, including billing Medicare, programs for the frail elderly and care of a broader range of student health problems.

Obstetrics and Gynecology Service: Charles F. Eades, M.D., Chief
The arrival of Dr. William Finlayson has added an experienced senior clinician to the service but staffing continues to be a major problem. Serving the MIT community needs in obstetrics, gynecology, gynecology/surgery and infertility areas requires the commitment of a larger staff and one which includes many female providers. During this year we have had approximately 8,000 annual visits, delivered 155 babies at Brigham and Women's Hospital, performed about 70 surgical procedures and provided ongoing consultation and treatment for over 50 women with infertility problems.

To facilitate advice and care for this latter group of patients an Infertility Consult Committee (ICC) was developed with Karen Halvorson, RNC, as coordinator. The committee is involved in evaluation and treatment, which includes referrals outside of MIT and in vitro fertilization programs. Of 21 patients seen and treated at MIT nine have become pregnant; of 21 individuals referred elsewhere, four pregnancies have resulted. Dr. Bruce Biller, internist and endocrinologist at MIT, has been an invaluable member of the ICC.

Educational activities have included staff participation in newer technologies, nurse practitioner programs, advances in diagnosis and treatment of osteoporosis and preceptoring midwives and medical residents.

Pediatric Service: Mark A. Goldstein, M.D., Chief
The first issue of SMALL TALK, a quarterly newsletter for families utilizing the Pediatric Service, was created written and distributed. This publication will also serve as an important resource for our student families, many of whom are internationals and new to the U.S. health care system. Several other initiatives were begun to encourage our student families in the west campus living groups to utilize the many educational resources of the Medical Department. The pediatric staff served as faculty for the year long medical/nursing staff pediatric inservice series. The staff also offered lectures to parents throughout the year as well as to students during IAP. Staff meetings

were formalized and the Pediatric Service defined and clearly stated a philosophy. Significant effort was made to promote and strengthen the concept of the primary pediatrician. With the hiring of a certified lactation consultant, an identified area of need among nursing families was rectified. During the coming year increased efforts will be made to make the MIT community aware of pediatric issues of concern and to encourage student family utilization of the services.

Psychiatric Service: Peter Reich, M.D., Chief
An enthusiastic and caring staff has continued to stimulate greater utilization of psychiatric services by the MIT community, resulting in an increase of 8.2 per cent in the number of patients seen. The increase this year reflected greater use by graduate students and non-student patients in contrast to last year when the increase was primarily from the undergraduate population. Paradoxically, freshmen are less frequently seen even though we hear so much about the stress of the first year at MIT.

Efforts to bring patients to our own facility resulted in 33 percent more admissions and an approximately 80 percent increase in days spent in the Inpatient Unit. Outside hospital admissions increased by almost 30 percent, a corresponding increase in hospital days of 41 percent but a decline in average length of stay of 10 percent. The area of outside hospitalization remains a challenging one to modify downward given the enormous expense involved in psychiatric hospital care. A few patients staying for the full 60 days of their benefits dramatically affected these statistics.

Trainees in the expanded training program continue to enrich the intellectual life of the service as well as providing care for patients. Marcia Yousik, C.S. has proven to be a valuable addition as psychiatric nurse practitioner, providing liaison for the Inpatient Unit, outreaching to undergraduates and health plan members in areas of direct care, engaging in health education activities and helping with follow-up of hospitalized patients.

Members of the Psychiatric Service are involved in many activities on the MIT campus and at Harvard Medical School. They serve as advisors, are involved in cancer support and other groups, teach in MIT, HMS and HST courses, as well as participate in a wide variety of Department and Institute committees. We regret the loss of two senior members to retirement, Lora Tessman, Ph.D., and Chester Pierce, M.D. We cheer the arrival of David Henderson, M.D., from MGH, and six new trainee affiliates.

Social Work Service: Ronald C. Fleming, LICSW, Chief
The Social Work Service continues to perform its role helping the Medical Department assist those who work, study, or do research at MIT with their health care needs. Further, Social Work Service staff contribute to the development and maintenance of an environment which facilitates such work, study, and research. The Social Work Service staff has found itself pressured by the demands of those who are in need due, part to the continuing attrition in public-sector services and the continuing recession. As financial pressures have come "closer to home," especially at Lincoln Laboratory, we are seeing the impact of this additional stress in a community known for a significant level of employment and academic pressure.

In the area of clinical activities the staff has creatively and flexibly responded to community needs through the use of groups. The groups offered during this academic year included: Parenting of Adolescents, Elder Care Support, Graduate Student Parent, Working Parents Support, Cancer Support (with the Psychiatric Service), Alcohol Support, Adult Children of Alcoholics, and Parents of Adolescents. The Social Work Service also operates as a "clearing house" for five different self-help organizations, including Alcoholics Anonymous and Overeaters Anonymous.

Community activities occupy another large area of involvement for members of the service, with participation in the Institute Personal Assistance Program, the Minority Student Concerns Group, the Summer Science Program, the Program for African-American Administrators, and work with Central Administration on the BUILDING ON DIFFERENCES program. The issues of elder care have been embraced through group activities, presentations and seminars. Other community and educational efforts have been dedicated to important topics and presentations such as minority health, family life at MIT for international wives, workplace stress, housing and living conditions of graduate students.

Finally, it should be emphasized that as a service within the Medical Department, social work staff regularly round with the Inpatient unit nurses, participate in quality assurance and other Medical Department committees and

consult on such topics as maintenance and use of the Inpatient Unit databases and other computer-related tasks.

Surgical Services: Stephen J. Healey, M.D., Chief
Three senior surgeons provide all of the general surgical care, including 125 major and 400 minor procedures during this year. Patients are transferred, as quickly as medical judgment allow, to the Inpatient Unit where convalescent care provided by the Nursing Service has been exemplary. Members of the group are expanding their training to provide laparoscopic surgery for our patients.

The orthopedic and urologic providers remain unchanged, and both are now structured as referral services from primary physicians. Members of the service have presented educational sessions for the nursing and physician staffs and have participated in subspecialty clinics.

Tertiary referrals to Mount Auburn Hospital and the MGH for thoracic, cardiac, neurologic, orthopedic and oncologic surgery allow our patients the best resources available for selected problems requiring surgical intervention.

Nursing Service: Janet V. Beyer, RNC, Maureen Dickey, RN, Co-Chiefs
The Nursing Service provides care in a variety of venues, including the CRC, the Inpatient Unit, Lincoln Laboratory, the ambulatory area of the Department, the After Hours Clinic and in support of functions such as exercise stress tests, infection control surveillance and service to the MIT community.

CRC activities include a Research Ambulatory Unit and overnight stays in the Medical Department Inpatient Unit. In the ambulatory area nurses coordinate protocols which include infusions and other procedures. Overnight patients are housed in the Inpatient Unit where the care is coordinated with the Inpatient Nursing Service. Efforts to increase the interaction and educational activities between the CRC and the inpatient nursing and physician groups are in motion.

At Lincoln Laboratory, Ms. Cantin and Ms. Beyer see approximately 350-400 patients per month. Backup medical input is provided by members of the Medical Department. Educational sessions have been presented at Lincoln and a prostate screening clinic was successfully held.

Continuing education activities have also been a central part of Nursing Service functions. In addition to programs at Lincoln Laboratory, a variety of conferences have been presented to the nursing staff by nurses and physician members of the Department. All Department nurses are certified in CPR. The pediatric group developed programs emphasizing emergency care and respiratory problems. The entire service held educational programs during National Nurses Week and numerous other educational programs were attended at MIT and elsewhere.

Community service activities of Nursing have been extensive and intensive and have included a freshmen screening clinic, international student orientation, health coverage for graduation and alumni week, a 2,500 student-served measles immunization program coordinated by Ms. Beyer, cancer screening clinics and outreach to the student population.

Infection control has been coordinated by Ms. Dickey and has provided surveillance, protective immunization reminders, outreach activities to Campus Police and others and record keeping and control of communicable disease reporting for the MIT population.

OTHER DEPARTMENTAL ACTIVITIES
Clinical Research Center (CRC): Naomi K. Fukagawa, M.D., Associate Director
The CRC submitted a competitive renewal application to the National Institutes of Health in October 1991, which was reviewed by a site visit committee on November 19-20, 1991, and received the highest priority score assigned to our renewal applications over the past decade. It was recommended for four years of support which will begin December 1992. Members of the CRC continue to participate in the Medical Department's activities (Quality Assurance, Pharmacy and Therapeutics, Medical Records and Safety Committees). Research and educational activities continued with several UROP students and postdoctoral fellows participating in ongoing research programs. Dr. Fukagawa conducted a freshman advisor seminar through the Division of Health Sciences and Technology. A one day research seminar on neurodegenerative diseases was held on May 15, 1992 with at least 100 attendees. Several research protocols are presently underway which utilize the Inpatient Unit as a site for the

conduct of the studies. Further integration of CRC activities into the Medical Department is anticipated in the near future.

Environmental Medical Service (EMS): Alan M. Ducatman, M.D., Chief
MIT was again without significant environmental health incidents. As in previous reports, we continue to note very large increases in regulatory requirements, with commensurate burdens upon faculty and EMS. Major progress can be reported in previously identified goal areas.

The Radiation Protection Office, responding to injuries of an untrained student, implemented a laser safety program which far exceeds federal or local requirements. It also supported the development of Alcator C-Mod at the Plasma Fusion Center and major operational initiatives at the Reactor Lab, including a core heavy water changeout. It demonstrated safety readiness of new hardware, monitors, and shielding provisions at the new Bates Linear Accelerator stretcher ring.

The Biohazard Assessment Office developed and implemented several teaching tools: an ongoing safety column in the TECH TALK "Employee Perspective Section," and a compliance program for the OSHA Bloodborne Pathogen Standard, including a highly successful and cost-effective video production. Testing of river water for field irrigation safety and collaboration with animal handlers for creation of Simian B virus free colonies on campus have also facilitated support operations that will consistently improve safety and reduce costs.

Last year the Industrial Hygiene Office assisted the successful creation of Chemical Hygiene Plans for the various department and centers at MIT. This year, it can announce significant progress towards implementation. Laboratory analyses continue to increase by 10 percent yearly, without major additional costs. The enormous jump in lead testing, without additional personnel, represents a cost savings in effective care of MIT patients.

The departure of Dr. Ducatman at the end of this academic year leaves a great void in EMS, compensated in part by the excellent group of individuals who remain and a superb organization of the service. Dr. Charles Billings will serve as interim Acting Director, assisted by Mr. Lou DiBeradinis. Dr. Ducatman's legacy for EMS, the Medical Department and MIT is the high level of excellence he leaves behind.

Health Education Service (HES): Bethany Block, M.D., Janet H. Van Ness, MSHH, Co-Coordinators
In the past year the HES maintained high visibility within the MIT community and can report a total of 8,635 health promoting encounters with students, faculty, staff, and members of their families. Besides continuing to coordinate its roster of core health promotion programs and the Department's popular IAP offerings, the HES was involved in the inauguration of several new student health initiatives, in the development of a well received health promotion series for those over fifty, and in several innovative interdepartmental program activities. Four hundred and sixty hours of direct health promotion programming were sponsored, organized or presented by the HES in the past year; more than half of these hours showcased the professional skills of MIT medical providers and health education staff. Several program efforts are high points of the last program year:

A number of new student health and health education programs were introduced, including blood pressure and cholesterol screening programs. The value of offering these services was affirmed by the positive reactions of the students and by referral of ma;ny who might not have otherwise had contact with the campus medical system.

Two programs offering students immediate answers to personal health questions were introduced during the second semester. Located in the HES Wellness Center in the Stratton Student Center, QUICKConsult's three weekly one-hour sessions were staffed by Department physicians who offered students the opportunity to walk-in for medical advice. Recognizing our students' comfort with computers, the HES also offered them the opportunity to ask their health questions over HEALTHe-mail.

The HES supported the concern for student health by housemasters and tutors, sections of the Office of the Dean for Undergraduate Education and Student Affairs, undergraduate government and social organizations, and Campus Police, by co-sponsoring or participating in nearly forty events ranging from large scale prevention awareness programs on sexually transmitted disease, alcohol abuse, date rape, food issues, and personal safety to dormitory study breaks on nutrition, safer sex, stress, and wellness. Training sessions offered to house masters and graduate resident tutors were especially well received this year. In particular, an "AIDS Summit," developed by the Deans Office and the Medical Department and presented by Dr. Michael Myers, received very high praise and, most

important, seemed to increase tutors' comfort in discussing the subject. This comfort plus widespread interest in "Truth or Consequence," an MIT student produced safer sex video, resulted in tutor led discussions of AIDS and sexually transmitted diseases in virtually every campus residence hall.

Finally, IAP 1992 workshops attracted 37 percent more participants than in 1991; more than two thirds of the sixty program presenters were Medical Department staff members. Several programs were collaborative efforts, including a five session series on Biomedical Ethics and Decision Making, co-sponsored with the MIT Women's League, and a three session series, Personal Health Strategies for African Americans, co-sponsored with the Association o African American Administrators at MIT.

Lincoln Laboratory Medical Clinic: Bruce J. Biller, M.D., Coordinator
The Lincoln Laboratory Clinic saw an increase in patients seen compared to last year. Installation of a computer/printer facilitated note and letter communications. A FAX machine will be available for transfer of clinical information, including electrocardiograms, when an M.D. is not on site.

In addition to direct patient care initiatives, educational programs attracted over 200 employees and approximately 60 men attended a prostate cancer screening clinic. We are revising a number of protocols used by nurse practitioners and have eased the ability of patients to obtain pharmacy services. Thanks to Dr. Biller and to the nursing staff the Lincoln facility is rapidly becoming more popular and more efficient in serving the needs of employees in this outpost facility.

Student Health Services (SHS): Mark A. Goldstein, M.D., Chief
Outreach efforts were expanded with the distribution of the Personal Physician Brochure to all incoming students, academic and freshmen advisors and key administrators. An increased Departmental presence was established through several health education initiatives in student living groups, the Student Center and Lobby 10. Despite outbreaks of measles in various areas of the country, the campus remained free of vaccine preventable diseases through an immunization program which included aggressive outreach, education and two well attended immunization clinics.

A cooperative teaching program was initiated between the Division of Adolescent and Young Adult Medicine at the Children's Hospital and the Student Health Service. Three physicians in the fellowship program were available to see students at the Medical Department during the academic year. During the coming year, the program will be expanded so the fellows will also participate in living group meetings. A pilot effort where MIT premedical students observed physician patient contacts at the Children's Hospital Adolescent Unit and then utilized these experiences to serve their peers at MIT was initiated.

The research study regarding AIDS attitudes and information among incoming MIT internal students was presented at the national college health meetings. A four year prospective study of freshmen who entered MIT in 1991 was initiated. This study, which has several facets, will examine the students' medical issues and usage of the Medical Department during their undergraduate careers. An age and gender matched control group will also be studied.

The activities of the SHS have been energized thanks to the leadership of Dr. Goldstein who chaired a task force group in the Department and also has been working with Associate Medical Director, Michael Kane, M.d. in a broad study of how to reach out to students in health education and care initiatives. This effort will include a significant Department contribution during R/O week activities as well as during the coming academic year.

Clinical Operations and Teaching: J. Christian Kryder, M.D., Coordinator
Specialty and Ancillary Services: The increase in size of the Health Plan membership may account for a 5 percent increase in visits to specialists. In addition, the nutrition service has been completely revamped and includes an individual with special expertise in eating disorder patients. The Department has added a physical therapist to the staff and the neurology service has undergone consolidation and reorganization. Other services have had only minor changes in personnel or in schedules.

MIT Health Plan - Utilization Review and Management: In fiscal year 1991, 572 patients were admitted to outside hospitals under either the Traditional or Flexible plans. Forty percent of these (237 patients) were Medical, and 34 percent (196 patients) were Surgical. Overall our hospital utilization for these patients is slightly under budget. All of these admissions are actively managed to assure appropriate care, timely discharge, and transfer, when possible,

to the MIT Inpatient Unit. All referrals to outside emergency rooms are reviewed and managed to assure quality, continuity, and appropriateness, of care. Cost containment opportunities currently under review include magnetic resonance imaging and electroencephalograms.

Teaching and Clinical Education: We have had three Mount Auburn primary care residents within the Department in the past year as well as one Podiatry resident. Additional activities within the Department include active development and management of HST Medical Engineering and Medical Physics Introduction to Clinical Medicine, a course which incoluded an intensive, 200 hour immersion over six weeks for seven MEMP students. In addition, within the past eight months, the Medical Department became a site for HST 201 "Real Medicine," a longitudinal largely ambulatory experience for students allowing long term involvement with preceptors and chronic patients. Currently we are working on additional initiatives which might be managed jointly between the HST Division of Harvard Medical School and the MIT Medical Department.

Administrative Operations and Management: Michael A. Kane, M.D., Associate Medical Director
Extensive changes occurred in the areas of administrative responsibilities and personnel. After a year long review of the mission and scope of the HES, Dr. Block was appointed Physician Coordinator to work with Ms. Van Ness in expanding services, especially directed towards students. The co-coordinators will work closely with Medical Department members involved in student health and with the Student Affairs Office and housemasters on the MIT campus.

Drs. Walter Jones and John Moses were designated as the first Emeritus Physicians and both will participate in Department activities and will also continue to serve MIT as Chairmen of COUHES and the Animal Care Committee respectively. Dr. Margaret Ross has ably succeeded retired Dr. Leonard Wolsky as Patient Advocate. Other administrative changes included Dr. Leigh Firn assuming responsibility for direction of the Off Hours Clinic and Dr. J. Christian Kryder resuming administrative responsibility for the primary care training program for Mount Auburn Hospital medical residents. Dr. David Diamond became Chairman of the Infection Control Committee and will participate in EMS activities.

MIT Health Plans: Linda L. Rounds, Executive Director
At the beginning of July 1992, the Traditional MIT Health Plan will begin its twentieth year while the Flexible MIT Health Plan will mark the start of its fifth year in operation. Both MIT Health Plans continue to satisfy members' health care needs at a reasonable cost and to provide a very positive moderating influence on the total cost of employee health care at MIT. Current enrollment levels are now at a total of nearly 8,000 members in the Traditional Plan and 2,000 in the Flexible Plan. This represents a growth of 300 members above the period ending one year ago. The MIT Health Plans now enroll one half of the employees choosing health insurance through MIT.

A major initiative during the past year involved reviewing the comparative financial performance of the two Plans in depth. The highlights of this analysis were presented to the Medical Management Board, the Executive Committee and the medical staff by Heather Ryan, Mary Smith and Linda Rounds. Our analysis indicated that the Flexible Plan has achieved the major goals that were established when the Plan was first offered in 1989. The Flexible Plan offers members greater choice within a managed care framework and has helped shore up the Medical Department's market share in a highly competitive health care environment. We are cautiously pleased by the Flexible Plan's initial financial performance. It has provided a safety net for those who want the freedom to choose any health care provider, while the Plan's managed care features have enabled it to become financially viable despite small enrollment, higher average age and some adverse selection.

Many individuals have been forced to abandon Blue Cross because of rapidly increasing premium costs. Often there individuals have joined the Flexible Plan and have done well in our managed care program, although the cost of caring for these enrollees has certainly been greater than for Traditional Plan members. Member education will be key in ensuring that those who choose the Flexible Plan understand that the rates may no longer be affordable if they choose to ignore the Plan's managed care features.

Personnel Changes
The following changes occurred for Administrative and Academic Staff during the period June 1, 1991 through May 29, 1992.

APPOINTMENTS

John A. Boyd	Neurologist
Elizabeth J. Engleberg	Clinical Psychologist
Stephen S. Falkenberry	Obstetrician/Gynecologist
Steven J. Faber	Pharmacist
William J. Finlayson	Obstetrician/Gynecologist
Michelle R. Fitzgerald	Assistant Radiation Protection Officer
Susan D. Freedman	Physician
Janice J. Guerriero	Inpatient Nurse
Julie F. Lavallee	Assistant Radiation Protection Officer
Lawrence J. Mambrino	Otolaryngologist
Jane E. Marsh	Inpatient Nurse
Eva E. Maury	Optician
Roger A. Proulx	Optician/Manager
David B. Sable	Obstetrician/Gynecologist
Andrew J. Scott	Physical Therapist
Arthur King Fan Tong	Dermatologist
Ann Morris Zaia	Inpatient Nurse

RESIGNATIONS/RETIREMENTS

Nancy R. Blum	Clinical Psychologist
Allen J. Brown	Clinical Psychologist
Linda Y. Buchwald	Neurologist
Richard S. Clement	Assistant Radiation Protection Officer
Joan M. Corr	Postdoctoral Fellow, Psychiatry
Anne L. Gilligan	Student Health Educator
Barbara A. Goff	Obstetrician/Gynecologist
Kristin J. Graham	Obstetrician/Gynecologist
Jane E. Marsh	Inpatient Nurse
Kathleen L. Marshall	Assistant to Executive Director
Marsha J. Mealey	Industrial Hygiene Chemist
John M. Moses	Physician (Retired)
Laura A. Nichols	Physical Therapist
Howard G. Smith	Otolaryngologist
Nancy E. Teiger	Nutritionist
Arthur King Fan Tong	Dermatologist
Martin Wingate	Gynecologist

Concluding Comment

The strength of the Medical Department comes primarily from the quality of the people who work here. The superb physical facility in which we labor and the stimulation that comes from the people we care for add greatly to our vitality. For want of space, many people are not noted individually in this report. In appreciation, many people should be mentioned. Without the creative efforts of this Department, we could not record each year the significant improvements put in place. However, I must recognize Ms. Linda Rounds, Executive Director and custodian of our exchequer, Dr. Michael Kane, Associate Medical Director and my wise counsel, and Dr. J. Christian Kryder, Assistant Medical Director for Planning, a creative colleague who also put good ideas to the practical test.

ARNOLD N. WEINBERG, M.D.

MIT Press

Fiscal 1992 was a very good year in terms of the publication of noteworthy new books and the launching of interesting journals, as well as in achieving positive financial results. In fact, considering the economic climate, last year was an extraordinarily good year.

Sales in the book division were $12,494,000, a hair shy of our budget, and seven percent ahead of last year. In the journals division, sales were $2,685,000, or nine percent ahead of last year. The Press produced a combined net proceeds-from-operations of $243,000 compared with ($29,000) in Fiscal 1991. After contributing $292,000 to the RA/TA portion of the benefits pool, the Press recorded a deficit overall of ($49,000), which was charged against it's general reserve account.

In international markets, sales grew by 14 percent. At $4,370,000, export sales are now 35 percent of our total business. In terms of dollar volume and percentage of sales, The MIT Press has the highest level of export sales of any university press.

We published 210 titles and launched two new journals. The list included the following noteworthy titles:

Barry	Technobabble
Benedict et al.	Cyberspace: First Steps
Blanchard et al.	Reform in Eastern Europe
Fudenberg & Tirole	Game Theory
Grossman & Helpman	Innovation and Growth in the Global Economy
Ito	The Japanese Economy
Mosser et al.	The Architecture of Western Gardens
Raymond	The New Hacker's Dictionary
Schmidheiny	Changing Course
Sloane	Hoffa

MIT authors:

Bertsekas	Linear Network Optimization
Blanchard et al.	Reform in Eastern Europe
Dornbusch et al.	Global Warming: Economic Policy Responses
Fisher	Econometrics
Fudenberg & Tirole	Game Theory
Kerrebrock	Aircraft Engines and Gas Turbines, 2d ed.
Krugman	Currencies and Crises
Krugman	Geography and Trade
Manning	MIT: Shaping the Future
Taylor	Income Distribution, Inflation, and Growth

Among the noteworthy books by non-MIT people from our scholarly and professional program were:

Bernstein	The New Constellation
Blume	Insight and Industry
Caplan	Language: Structure, Processing, and Disorders
Chapman	Vision, Instruction, and Action
Churchland & Sejnowski	The Computational Brain
Cohen & Arato	Civil Society and Political Theory
Crimmins	Talk about Beliefs
Diamond	The Realistic Spirit
Doheny-Farina	Rhetoric, Innovation, Technology
Drescher	Made-Up Minds
Ghirladucci	Labor's Capital

Goldstein	A Different Sort of Time: Jerrold Zacharias
Habermas	Postmetaphysical Thinking
Hatcher & Quinn	Data-Parallel Programming
Honneth	The Critique of Power
Lasnik & Saito	Move alpha
Leyton	Symmetry, Causality, Mind
Lichtenberg	Corporate Takeovers and Productivity
Lobo et al.	Foundations of Disjunctive Logic Programming
Manne & Richels	Buying Greenhouse Insurance
Manzini	Locality
Russell & Wefald	Do the Right Thing
Tyler	Spoken Language Comprehension
White	The Unity of the Self

New hardcover books for trade and general audiences included:

Diamond	The Media Show
Donnelly	Architecture in the Scandinavian Countries
Etlin	Modernism in Italian Architecture, 1890–1940
Heims	The Cybernetics Group
Hunt	Gardens and the Picturesque
Kosuth	Art after Philosophy and After
Lythgoe	Fishes of the Sea
Massumi	A User's Guide to Capitalism & Schizophrenia
Neumeyer	The Artless Word
Stafford	Body Criticism
Templer	The Staircase
Thompson	Recycled Papers: The Essential Guide
Varela et al.	The Embodied Mind
Vidler	The Architectural Uncanny
Wesson	Beyond Natural Selection

Books published primarily as texts included:

Beakley et al.	The Philosophy of Mind
Beck et al.	Hematology, 5th ed.
Becker et al.	Behavioral Endocrinology
Bertsekas	Linear Network Optimization
Buser & Imbert	Audition
Cardoso & Helwege	Latin America's Economy
Demers & Farmer	A Linguistics Workbook, 2d ed.
Ereshefsky et al.	The Units of Evolution
Freidin	Foundations of Generative Syntax
Friedman et al.	Essentials of Programming Languages
Fudenberg & Tirole	Game Theory
Grossman et al.	Imperfect Competition and International Trade
Ito	The Japanese Economy
Kerrebrock	Aircraft Engines and Gas Turbines, 2d ed.
Margulis et al.	Environmental Evolution

Editors in the Acquisitions Department include: Laurence Cohen (Linguistics, Philosophy, Technology Studies); Roger Conover (Architecture, Design Arts); Terry Ehling (Computer Science, Artificial Intelligence); Robert Prior (Computer Science, Artificial Intelligence); Henry and Elizabeth Stanton (Cognitive Science); Fiona Stevens (Neuroscience); Madeline Sunley (Environmental Science); and Terry Vaughn (Economics).

BOOK PRODUCTION

Under the direction of Michael Sims, managing editor, and Terry Lamoureux, production manager, the editorial and production departments continued to add quality to our publications. The design department, under Yasuyo Iguchi upheld the Press tradition of award-winning jacket and book design, garnering honors from the New England Book Show, the Association of American University Presses, Print Magazine, and The American Institute of Graphic Arts.

COMPARATIVE OPERATING RESULTS (in thousands)

	Fiscal Year 1992	Fiscal Year 1991 Actual	Fiscal Year 1990 Actual
Total Net Book Sales	$ 12,494	$ 11,660	$ 10,207
Cost of Sales	5,760	5340	4,587
Gross Margin on Sales	6,734	6,230	5,627
Other Pub. Income	129	174	164
Bookstore Net	125	120	110
Total Income	6,988	6,614	5,901
Operating Expense	6,864	6,684	6,066
Net Books Division	124	(70)	(165)
Journals Net	114	40	121
Net Pub. Operations	**238**	**(30)**	**(44)**
Add: Investment Income	127	144	168
Subt: Interest Paid MIT	(122)	(143)	(52)
Net Operating Gain (Loss)	**243**	**(29)**	**72**
Deduct RA/TA Contribution	(292)	(264)	(244)
Net to Reserve	49	(293)	(172)

Faculty serving on The MIT Press editorial board in 1991-1992 were Professsors Harold Abelson, Stanford Anderson, Penny Chisholm, Peter Diamond, John P. Longwell, Albert Meyer, Daniel Osherson, Robert Silbey, Merritt Roe Smith, and Carl Wunsch. 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 twice during the year. Members of the board are 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; Jack Schulman, former Director, Cambridge University Press; Robert M. Solow, Chairman of The MIT Press Editorial Board, 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, philosophy and the newest list, neuroscience account for about 90 percent of our total sales in this last fiscal year.

BOOK SALES

Customer Type	Fiscal Year 1990	Fiscal Year 1991 (in thousands)	Fiscal Year 1992
College Bookstore	$ 1,959	$ 2,019	$ 2,142
Retail Bookstore	2,071	2,360	2,264
Wholesaler/Jobber	2,017	2,463	2,595
College/University Library	135	149	133
Direct Mail	509	586	662
To Individuals	951	989	1,219
TOTALS	7,641	8,566	9,016

Total dollar sales for the Press increased in FY1992 by 7.2 perceont to $12,493,800 and total unit sales increased by 6.6 percent to $682,860. Again, sales outside the United States were exceptionally strong, comprising 35 percent of total sales.

INTERNATIONAL SALES

Fiscal year 1992 was, for the most part, a time of solid growth in export sales of MIT Press books. The 14 percent increase in export sales exceeded budget by almost $450,000. Highlights: sales to Australia/New Zealand up 22 percent; Latin America, led by Mexico, up 29 percent to over $45,000; the vigorous economies of Korea, Taiwan, Hong Kong, and Singapore up 24 percent to $190,000. Changing Course, published by MIT Press to coincide with the 1992 Earth Summit, brought in over $277,000 in export revenue late in the fiscal year. Lowlight: Canadian sales decreased for the first time in over a decade. The introduction of the Canadian Goods and Services Tax in January of 1991 has permanently altered the book market there, and MIT Press felt the effect of that alteration this year. With market restructuring now completed, Canadian sales growth commensurate with growth in the U.S. should resume in Fiscal 1993. The table below recaps this year's international sales experience and place it into context with previous years and with the Press' overall book sales results.

International Book Sales FY 1990 - 1992

	Fiscal Year 1992	Fiscal Year 1991	Fiscal Year 1990
Australasia	$ 221,500	$ 181,400	161,500
Canada	534,600	558,600	509,800
Japan	675,000	613,700	551,300
UK/Continent	2,061,900	1,891,800	1,502,500
Other	872,600	580,000	437,600
TOTAL EXPORT	4,370,600	3,825,700	3,162,500
percentage of total	35.1	33.2	31.8

SUBSIDIARY RIGHTS

The focal point of our subsidiary rights program continues to be the sale of translation rights. As predicted, the worldwide recession made its sharpest impact in FY 1992; although income was down in this category by 8 percent since FY 1991, it was well over the projections made a year ago. Publishers abroad continue to be cautious in their purchases; they are slow to reach decision and offer very conservative advances. In addition, because of new tax regulations in place in several Western European countries, we must now obtain documents from the IRS for every European countries, we must now obtain documents from the IRS for every sale, a step that can delay payment of foreign advances and royalties for months. Our list continues to have. Our list continues to have a very high visibility abroad, and we show a pattern of increasing activity in Germany, a long-term goal of our program. The continuing demand for our books reassures us that income from translation rights continues on course. This year's income derived from English language

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reprints was far in excess of our projections. We are now seeing the effects of the 1991 court decision against unauthorized copying and our success at streamlining procedures so we can handle the growing numbers of requests for permission to photocopy.

As predicted, the amount derived from sales to book clubs showed a sharp drop – 65 percent from Fiscal Year '91. This is due to the increasing emphasis on the part of book clubs on mass market titles, and the ever-tighter margins that smaller, specialized bookclubs must adhere to. We continue to sell to Newbridge's Library of Science, but only when it is possible to do so in exchange for standard royalties.

Although subsidiary rights income decreased by 14 percent in Fiscal Year '92 since Fiscal Year '91, it exceeded projected income by about the same percentage.

Subsidiary Rights Income FY 1987 - FY 1989

	Fiscal Year 1992	Fiscal Year 1991	Fiscal Year 1990
Translation Rights	$ 141,393	$ 155,042	$ 148,132
Book Clubs	17,066	48,458	25,986
Reprint Rights	74,370	67,801	61,281
AudioVisual	741	1,000	200
	233,570	272,301	240,042

PROMOTION, PUBLICITY, AND DIRECT MARKETING

Textbook sales in FY92 were the best ever totalling $2,252,122. This represents a 4.8 percent increase over last years sales. Unit sales also increased by 1.9 percent (162,320 units in all) over last year. New titles contributing to sales include: Fudenberg & Tirole: Game Theory; Lynn-Jones: The Cold War and After; Krugman: The Age of Diminished Expectations in paperback. Twenty-one promotions were prepared during FY92. These were mailed to 46,068 professors in the U.S. and Canada.

Direct mail traceable sales for the year were $664,111, up 13 percent from Fiscal Year '91 and 28 percent over the past two years. Unit sales (25,451) also increased by 6.8 percent over Fiscal Year '91 and by 12.4 percent over two years. Economics was once again the highest income producer with sales of $95,942, followed by Computer Science/AI ($80,056), Art & Architecture ($46,132), Cognitive Science ($43,341), Philosophy ($36,480), and Neuroscience ($33,805). Bookclearing sales from Fiscal Year '91 and Fiscal Year '92 contributed approximately 28 percent of direct mail sales for the year with an income of $188,679.

Sales from the Exhibits Program were $119,440, an increase of 13.6 percent over last year, with another $2,500 in orders expected from meetings held at the end of the fiscal year. Standout meetings generating over $15,000 each in sales were the Neuroscience meeting and the Allied Social Science Association meeting, both held in New Orleans.

Advertisements for MIT Press books appeared in 391 trade and scholarly journals and magazines, as well as conference programs. Two hundred and forty one (241) or 87 percent of these ads were produced in-house on the Macintosh. A major advertising campaign was implemented for the Stephan Schmidheiny book, Changing Course with ads appearing in The New York Times, The New York Times Book Review, Foreign Affairs, and The Economist.

MIT Press books received favorable attention in book review sections, magazines, and professional and scholarly journals covering a variety of fields in the US and abroad. The New York Times alone reviewed David E. Nye's Electrifying America, The Architecture of Western Gardens, edited by Monique Mosser and Georgest Teyssot (selected by Publishers Weekly as one of the "Best Books of 1991"), Eric Raymond's The New Hacker's Dictionary, Robert Harbison's The Built, The Unbuilt, and the Unbuildable; From Gaia to Selfish Genes edited by Connie Barlow (featured in the Book Review's "Noted With Pleasure" column),

and Changing Course, a report on business and the environment prepared by Stephan Schmidheiny and The Business Council for Sustainable Development. Changing Course was widely reviewed in environmental journals as well as in major magazines and newspapers including Business Week, The Economist, The Financial Times, The Wall Street Journal Europe, and The Boston Globe.

Reviews of The New Hacker's Dictionary also appeared The Washington Post, Science News, PC Magazine, Information Week, Mondo 2000, The Chicago Tribune, Personal Computer World, New Scientist, AI Expert, and in William Safire's "On Language" Column. And Joan Lisa Bromberg's The Laser in America received high praise in The American Journal of Physics, Physics World, The Sciences, Nature, Science Books and Films, and the Times Higher Education Supplement.

Press books and journals were recognized for their contributions to fields including architecture, landscape design, the philosophy of science, and the history of technology. They received the following awards:

Public Works Historical Society Abel Wolman Award: David E. Nye's Electrifying America was named the most outstanding contribution of 1990 to the study of public works history. The author received a prize of $1,000.

The London School of Economics Lakatos Award: This prestigious award for outstanding contributions to the philosophy of science was presented to Elliott Sober for his Reconstructing the Past: Parsimony, Evolution and Inference, a Bradford Book published by The MIT Press in 1989. The Award Committee agreed that Reconsructing the Past "makes a major contribution to the philosophy and methodology of evolutionary biology." Sober received the award and a cash prize of £10,000 in March of 1992.

Association of American Publishers, Professional and Scholarly Publishing Division (AAP/PSP) Awards: Richard Etlin's Modernism in Italian Architecture was named the most outstanding book of 1991 in the category of Architecture and Urban Design; and TDR: The Drama Review, and MIT Press journal, was recognized for Excellence in Journal Design and Production.

American Institute of Architects' International Architecture Book Awards: both James Ackerman's Distance Points and Richard Etlin's Modernism in Italian Architecture were winners in the History and Theory category, and The Architecture of Western Gardens edited by Monique Mosser and Georges Teyssot was recognized in the Architecture and Related Arts Category.

The American Society of Landscape Architects Awards: The Society recognized The Meaning of Gardens, edited by Mark Francis and Randolph Hester, as an oustanding project which helped to "raise the public's awareness of landscape architects."

JOURNALS

In FY92, the Journals Division had gross sales of $2.8 million, a 12 percent increase over last year. $163,500 was added to the deferred subscriptions reserve account, a 15 percent increase. New total reserve at year end was $1,256,800. The two journals joining the program at year's end – Presence: Teleoperators and Virtual Environments and Journal of Economics and Management Strategy – had a combined loss of $112,450 but added $37,538 to the deferred subscriptions reserve account. Mimar left our program to go to Rizzoli Publications. Overall, the program's net improved from a $945 loss in FY91 to a $67,018 surplus in FY92.

The division ends the year publishing twenty-four journals. The others are: Assemblage, Computational Linguistics, Computer Music Journal, Design Book Review, Design Issues, Design Quarterly, The Drama Review, The Ecologist, Journal of Interdisciplinary History, International Organization, International Security, Journal of Cognitive Neuroscience, Linguistic Inquiry, Mimar, NBER Macroeconomics Annual, Neural Computation, October, Quarterly Journal of Economics, The International Journal of Robotics Research, The International Journal of Supercomputer Applications, Tax Policy and the Economy, Thesis Eleven, and The Washington Quarterly.

FRANK URBANOWSKI

Personnel Office

A great deal of time and thought has been expended on the early phase of implementation of a new human resource information system. Input was sought from all members of the Office and from many members of the community we serve, as to the changes needed to provide more effective, efficient service. Using data obtained through business and functional analyses, we were able to define our current mode of operation, understand how our system is inadequate, where our processes are redundant, how to best meet the needs of the community and our own internal needs, and to identify a software package flexible enough to serve now and in the future. I want to give special thanks to Stephen D. Scarano, Assistant to the Vice President, for Information Systems, who graciously accepted the task of Project Manager. Steve has worked tirelessly on the project, has shown enormous patience, and has been a source of comfort to me in explaining how to arrive at a given point in this particular project.

The staff in the Office has shown enormous fortitude in ensuring that the day-to-day operations have suffered little if at all as we forge on from one phase to the next in the project. I thank them all.

Margaret Ann Gray, Stephen A. Fairfield, Jeffrey R. Zeman, and David B. Achenbach joined the Office during the past year. Ms. Gray as Training and Development Coordinator, Dr. Fairfield as Manager of Special Community Services, Mr. Zeman as Benefits Counselor, and Mr. Achenbach as Assistant Manager of Labor Relations. Other staffing changes included promotions from Support Staff for Nancy A. Miller and Ann B. Coakley, both to Benefits Counselors, and to Sandra Titus to System Support Consultant. Barbara Engel transferred from the Office of the Vice President to replace Cynthia L. Vallino who is on leave for one year.

As of June 30, 1992, of the total of 28 administrative staff in the Personnel Office, 6(21%) are underrepresented minorities and 20(71%) are women. (In 1991, these figures were 5(19%) and 20(77%) of 26). In the Office of Special Community Services of the total of 4 Administrative Staff, there are no underrepresented minorities and 3(75%) are women.

As of June 30, 1992, of the total of 24 support staff in the Personnel Office, 3(13%) are underrepresented minorities and 18(75%) are women (In 1991, the figure were 4(19%) and 15(60%) of 25). In the Office of Special Community Services the number of underrepresented minorities on the Support Staff is 1(33%) of a total of 3 and 3(100%) are women.

JOAN F. RICE

COMPENSATION OFFICE

The Compensation Office's mission is to provide fair and equitable salary administration for the Institute's faculty, staff and employees. Our work is interesting and diverse, and typically involves consultation with a broad spectrum of the MIT community, including Senior Officers, Department Heads and Center Directors, and a wide cross-section of supervisory and non-supervisory personnel. Our activities are focused in the following major areas: data gathering; data analysis; preparation of recommendations for annual review allocations to the Executive Committee of the Corporation; preparation, implementation, and analysis of annual reviews; maintenance of the Institute's two job classifications systems; monitoring of all payrolls for salary equity; and preparation of numerous special studies and statistical reports.

The following quantitative detail may help to describe the scope of the Compensation Office's activities:

Each year we conduct two major national surveys, one relating to Faculty salaries, and one to Administrative Staff salaries. We collect data from approximately sixty-five universities and businesses across the country. This year's participants reported data on approximately 24,400 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 more than 40 outside surveys.

We initiated nine separate salary reviews covering approximately 7,300 members of the Institute's faculty and staff.

We reviewed a total of 77 separate requests for reclassification in the Institute's Administrative Staff Classification Program, including 44 requests to assess newly created positions, 10 requests for promotions from Support Staff, and 23 requests to reevaluate existing positions.

We continued to make progress in developing our personal computer systems to support our various activities. For example, organizations that participate in our two national salary surveys now typically submit data on diskettes. We continued to develop new spreadsheet and database applications that facilitated the input and analysis of these survey data, including a number of "macro-driven" spreadsheets. We look forward to the challenges and benefits we expect from the Personnel Department's new CYBORG computer system, which will be installed later next year.

I would like to thank my associates Susan A. Lester, Dineen M. Doucette, and Judy K. Raymond for their outstanding contributions and good spirits. They work very hard to accomplish our many and varied assignments, yet always remain open to new ideas and new practices.

KERRY WILSON

BENEFITS OFFICE

It was another year of building for the Benefits Office. At the end of December, the Benefits Office became fully staffed. The following four months were devoted to classroom, on-the-job and team meeting training. Lincoln Benefits Office staff and Benefits Accounting Office staff joined our training sessions.

The Office implemented changes in the Long Term Disability Plan and Life Insurance Plan to comply with the Older Workers Benefits Protection Acts.

Members of the Office were involved in the design and implementation of the benefits section of the Cyborg personnel system. In addition, we designed a new PC-based application for the calculation of the tax deferred annuity maximum exclusion allowances. This application will provide in-house batch and individual calculations, eliminating the manual data gathering process and lengthy turnaround time for sending the calculation request to the carrier. Implementation is scheduled for August 31.

We participated with the Benefits Accounting Office in Phases I and II of the review of pension administration. Members of the Office were interviewed and provided documentation on policies, procedures, and problems.

The Office began the financial and design review of the impact of the Financial Accounting Standard Board Number 106 on our retiree medical obligations. The Benefits Office worked with the Comptroller's Accounting Office and the Treasurer's Office to draft the retiree medical plan and trust documents. Both were adopted in June.

Updates were made to several communication pieces. This process is expected to continue to the end of calendar 1992 when we are required by law to deliver updated summary plan description booklets on each of our benefit plans to eligible employees.

There was a 10% increase in the number of pension estimate requests. We processed over 1200 pension illustrations and counselled 147 employees who retired.

A new release of the pension calculation system was implemented which eliminated the need for manual adjustments.

During the last half of the year the Benefits Office enthusiastically prepared for our move in August to E19-411.

DEBORAH KELLEY

FACULTY AND STAFF INFORMATION SERVICES

Faculty and Staff Information Services has the responsibility to acquire, maintain, and provide employment information about faculty, staff, and other persons affiliated with MIT and to ensure the currency, privacy and accuracy of this information.

The office processed more than 14,000 appointments and changes. In addition, the office continues it's role in the processing of salary reviews, in the servicing of the many data requests received from within the Personnel Office and the MIT community, in responding to external employment verification requests, and in the production of the staff telephone directory.

In the systems and programming area, there continues to be a demand for modifications and reports. Approximately 450 programs are maintained in the office, representing salary reviews, survey data, labor relations statistics, reconciliation reports, and departmental information listing and labels.

Preparation for implementation of the new Human Resource Information system, a CYBORG Software Package, began in July. SQL Solutions was contracted to perform a detailed process and data modelling analysis. Through this effort Faculty and Staff Information Services identified all of the data flowing in and out of the Office . SQL merged this information with information from the other sections of Personnel and produced electronic process and data models, entity-relationship diagrams and a complete data dictionary. Faculty and Staff Information Services also provided support to SQL. These models have been used in the implementation phase and served as the basis from which to map Personnel functionality and information requirements to the Cyborg package.

Digital Equipment Corporation, (DEC) was selected to implement the Cyborg system. For this project DEC teamed with Cyborg Systems and started implementation planning in January of this year. DEC proposed a two-part approach to the project: a scoping effort and an implementation effort. The purpose of the scoping effort was to define both the technical and business management tasks required to move Personnel from its current way of doing business to the new system. The scoping effort resulted in a detailed project plan that addressed both business and technical requirements for the implementation effort.

Through the scoping effort DEC introduced TOP Mapping to members of the Personnel Office. It was important for the Personnel Office to obtain needs and directions of key constituencies. TOP Mapping proved to be the appropriate vehicle for obtaining views from departments on current problems in personnel processes and practices. The results were suggestions and ideas as to how the processes and practices can be enhanced to better serve the Institute community.

This fiscal year has been extremely busy. Through all of the regular day-to-day activities and the additional effort required to reach our target date of September, 1992 for implementation, the office has managed to maintain its level of support.

CLAIRE L. PAULDING

LABOR RELATIONS

The Labor Relations Office is responsible for negotiating and administering the collective bargaining agreements with five bargaining units representing approximately 1,700 MIT employees. Duties also include representing MIT in grievance arbitrations and in some cases before administrative agencies.

In October, 1991, this office successfully concluded new two-year Agreements with the Service Employees International Union Local 254 (SEIU), (Campus and Lincoln Laboratory/Haystack bargaining units) and the Research, Development & Technical Employees' Union (RDTEU). Shortly thereafter we also reached agreement with the Campus Police Association (CPA). All four Agreements are for the period July 1, 1991, through June 30, 1993, and provide for wage and benefit changes consistent with MIT budgetary guidelines.

In June, 1992, negotiations began with the Security Officers Independent Union (SOIU), for a new Agreement to replace an Agreement scheduled to expire June 30, 1992. Pursuant to a National Labor Relations Board election in May, 1992, this employee organization was selected to succeed the Independent Union of Plant Protection Employees (IUPPE), Local #14. The election of a new union to represent the Lincoln Laboratory Security Officers delayed the start of negotiations for a new Agreement, however, we are hopeful that a new Agreement will be reached in a timely manner.

The number of grievances filed declined compared to the prior year. The number of arbitrations remained relatively low as many grievances were settled during the grievance process. Two arbitrations have been held and awards are pending. A third was settled after two days of hearings. Two cases involved promotional issues and the other case involved the termination of an employee for unavailability for work.

During this period, worked closely with Lincoln Laboratory Group 12 and Officials of Local 254 in arranging for new second shifts in several trade shops in an effort to improve efficiency of Group 12 operations. In addition one of the trade shops was restructured and a new classification added in order to keep up with changing technology.

David B. Achenbach was hired as Assistant Manager of Labor Relations. David comes to MIT after spending three years with the City of Boston as Assistant Corporation Counsel with the Office of Labor Relations and prior to that spent several years working for Boston University.

ROBERT J. LEWIS

PERSONNEL SERVICES AND EMPLOYMENT

During the past year Personnel Officers have continued to be an important resource for their departments in working with supervisors to solve employee relations problems and in assisting employees as they make job or overall career changes. Although the job market for internal transfers remained tight, the spring brought a slight increase in job opportunities. Personnel Officers have also been available to discuss policy matters and other concerns with various department employee groups.

As departments sought to improve their affirmative action efforts, the Office contracted with a minority agency in March 1992 to assist us with the search and placement of more minorities for Administrative Staff positions.

We welcomed the opportunity to work with Margaret Ann Gray, our new Training and Development Coordinator, as she assessed the Institute's training needs and began to establish new programs for the community.

Employment Activity

Employment opportunities during the last four years have shown a steady decline from a high of 1176 in 1988-89 to 544 in 1991-92.

The current year's openings included 288 support staff, 91 administrative staff, 20 academic staff, 113 research staff and 32 service staff. 2,269 individuals applied for support staff openings and in addition, approximately 17,707 resumes were processed by the Personnel Office staff. The hire rate increased by 12% from 445 to 498 people and the number of Institute employees transferring to new positions remained approximately the same (126 individuals).

In closing we would like to note that many members of the section contributed to the analysis and development of a new Applicant Tracking System which we expect to be operational by the Fall of 1992. This should result in faster job placement and better communication for all applicants regarding the status of jobs.

SALLY H. HANSEN AND ELIZABETH K. MULCAHY

OFFICE OF SPECIAL COMMUNITY SERVICES

The Office of Special Community Services' (OSCS) overall mission is to augment the quality of life for MIT employees by helping to meet their individual needs through the provision of a range of services including: consultation and referral for child care or parenting needs; employee and retiree recognition; referral to meaningful volunteer positions and activities; charitable giving opportunities; cultural and entertainment activities; and assistance in the development of family and work-related Institute recommendations.

The consolidation and integration of programs within the OSCS has been completed this past year with the President's appointment of MIT's Council on The Family and Work, chaired by Professor Jack L. Kerrebrock and staffed by Stephen Fairfield, Family and Work Council Executive Officer and Manager of the OSCS. The Council will serve in a deliberative capacity and make periodic reports to the Institute's senior officers concerning family and work-related issues and their impact on MIT's faculty, staff and students.

Services consolidated within the OSCS include the Child Care Office, the MIT Activities Committee (MITAC), the Quarter Century Club, the United Way Campaign, the Annual Retirement Dinner, and the MIT-Cambridge Chapter of the American Association of Retired Persons. In addition an Employee and Retiree Volunteering Program is being developed.

Child Care Office

This year has seen the definition and major expansion of the two distinct programs created within the Child Care Office (CCO): Child Care Resource and Referral Services led by Kathy Simons, Administrator, and Parenting Programs led by Rae Simpson, Administrator. The Office is also staffed by J.B. Sweeney, Senior Office Assistant. Both programs received national recognition this year as

at professional meetings and selection as one of four programs around the country to be featured in a work-family publication by the Family Resource Coalition. One reflection of the CCO's growth is the size of its mailing list, which now includes over 1400 MIT families who have been served by CCO programs.

The Child Care Resource and Referral Services provided individual consultations, briefings, information packets and workshops on child care, schools, summer camps, and children's programs to approximately 300 families, representing a 25% increase in employees and students served compared to last year. There has been a marked increase in the number of inquiries regarding infant care, in particular in-home and part-time infant care, as well as elementary school placement. The number of campus family child care homes in the MIT network has remained generally between 12 and 15. Services to child care providers were expanded to include several new parent/child programs at Eastgate and Westgate.

The Parenting Programs administrator coordinated and/or ran a full series of fall and spring parenting seminars including 20 workshops, 4 workshop series, and a weekly support group, attended *in toto* by over 300 participants. A number of other events were cosponsored and arranged under the aegis of Parenting Programs. More than 100 parents and other family members were seen for individual consultations on balancing work and family, childrearing problems, and other family issues. Consultations, seminars, and resource materials increasingly represent the interests of a diversity of age, gender, racial and ethnic background, family structure, sexual preference, and other factors.

The Child Care Resource and Referral Services Administrator continues to act as a resource to MIT's affiliated campus child care center, Technology Children's Center. Technical support is provided to the Lincoln Laboratory Children's Center and Child Care Office. A summer camp briefing was held at the Laboratory for the first time, as was an eight-session parenting workshop.

MIT Activities Committee (MITAC)

This year MITAC organized 88 events attended by approximately 5,000 members of the MIT Community. In addition, more than 20,000 movie and other discount tickets were made available. At the end of its first decade of service to the MIT community MITAC staff and dedicated volunteers have planned and executed 650 special events and have continued to expand its wide range of cultural and recreational discount offerings. Beginning in February, 1992, service hours at the MITAC office at Lincoln Laboratory were doubled with the addition of Carrie Young who is a part of a pilot program to explore the feasibility of expanding MITAC services there. This pilot program is expected to be reviewed at its conclusion in December, 1992.

Quarter Century Club

The Quarter Century Club has approximately 2,400 members, made up of employees, retirees, and honorary members. The Club's annual outdoor picnic was held in the Johnson Athletics Center on August 15, 1991, because of threatening weather. Over 850 guests feasted on traditional picnic fare and were entertained by Professor Jay Keyser and his jazz group. One hundred and ten women gathered for the Silver Club luncheon on October 15, 1991, held at the MIT Faculty Club. The annual holiday party on December 12, 1991, was again held in the Sala de Puerto Rico of the Stratton Student Center, and was attended by over 600 Club members. The Annual Meeting and Induction of 149 new members was held on March 24, 1992. The induction ceremony took place in the Bartos Theatre, Wiesner Building, followed by the reception for all members in Morss Hall, Walker Memorial. James J. Fandel, President of the Club, opened the program and Constantine B. Simonides, Vice President and Secretary of the MIT Corporation spoke to the group, thanking them on behalf of MIT for their more than 3,700 years of service.

The Quarter Century Club's 12-member board, led by Chairman Daniel H. Gould met on August 15 and October 22, 1991 and May 18, 1992. Current officers of the Quarter Century Club are: James J. Fandel, President; Francis B. Magurn, Vice President; Winifred T. McDonough, Treasurer; and Mary Frances Daly, Secretary.

United Way Campaign

The 1991 United Way Campaign was successful as MIT surpassed its goal of $310,000, with 2,292 contributions totaling $323,129.16. The single largest donation was $10,000, and the average donation was $140.86.

Annual Retirement Dinner

The Annual Retirement Dinner was held in Morss Hall, Walker Memorial, on Tuesday, June 2, 1992. Hosted by President Charles M. Vest, it was attended by 175 guests, including retiring employees, their guests, Quarter Century Club Board members, and other senior MIT administration. The evening began with a social hour; during the dinner program the names of each of the 142 retirees were read by Rebecca M. Vest, MIT's First Lady; Mark S. Wrighton, Provost; Winifred T. McDonough, Quarter Century Club Treasurer; and William R. Dickson, Senior Vice President, who also served as master of ceremonies for the event. As the honored guests departed the music- and balloon-filled hall, they accepted their framed certificates.

MIT-Cambridge Chapter of the American Association of Retired Persons

The OSCS provides staff support and office space to the MIT-Cambridge Chapter of the American Association of Retired Persons. The Chapter, with a total membership of 187, is led by six officers and an 18-member board. The Board meets quarterly to organize chapter meetings and sponsors several leisure excursions each year.

OSCS Staff

OSCS staff includes: Stephen Fairfield (Manager); Barbara A. Gilligan (Senior Office Assistant); Susan L. Kendall (Administrator); Kathy Simons (Administrator); Rae Simpson (Administrator); JB Sweeney (Senior Office Assistant); and Diane B. Tavitian (Administrative Assistant);.

STEPHEN A. FAIRFIELD

Public Relations Services

This past year there were extraordinary demands on the talents and resources of many individuals and offices in the Public Relations Services -- particularly given the shifting ground of relations between the university and the federal government. The staff rose to the occasion -- meeting those demands, and going beyond response to the pressures of the moment to devote considerable attention to ways to improve our planning and operations.

Among the highlights of this year were the News Office' achievement of positive media coverage and commentary at both the local and national levels on a number of key issues of importance to MIT -- and especially on matters relating to the indirect costs of research and on financial aid practices. In terms of improved operations, several PRS offices implemented enhanced computer-based information and production systems. These included the design and installation of a computerized database for the International Scholars Office; the creation by the News Office of a computerized file of newspapers across the country, for use in "hometowning" stories about MIT students and faculty; and the use of electronic publishing in Design Services in ways that lowered costs, shortened production time, and allowed for greater design flexibility. The third major achievement was the introduction of the principles and processes of total quality management in the PRS management team and in the work of the Communications Office.

Major goals for the coming year include the following: 1) continue to learn and apply the principles of total quality management in our work, 2) enhance media relations and participate in a major review of communications organization and activities at MIT, and 3) participate in planning for conference and special events facilities at or near the Institute and in assessing how better to use housing and dining facilities during the summer.

The contributions of the Public Relations Services, and its plans for the future, are the product of an exceptional group of individuals who hold themselves to high standards of achievement, mutual regard, and teamwork. I am fortunate to have such a talented and dedicated group to work with.

KATHRYN A. WILLMORE

COMMUNICATIONS OFFICE

The Communications Office produces the Institute's annual reference publications, including two issues of the MIT Bulletin, the Courses and Degree Programs Issue and the Summer Session Catalogue; Reports to the President; Report of the Treasurer; and the Faculty /Staff and Student Directories. Additional publications such as the Report of the President and Committees of the Institute appear as *Tech Talk* supplements. The office's overarching goal is continuous improvement in the format and content of its publications, bringing production cycles in-house and on-line to the greatest extent possible.

Three major achievements this year involve improved management processes, new publications, and increased savings in production costs.

First, the introduction of a new approach to management, referred to as "total quality management," had a significant influence on the Communications Office. Communications Manager Barrie Gleason represented Public Relations Services on Vice President Simonides' Working Group on Quality Management at MIT and attended Professor Bitran's Workshop in TQM, a 10-week course in the Sloan Fellows' Program. This exposure influenced day-to-day operations by providing a context within which staff members were encouraged to focus on work processes as the key to improving quality of service. Improvement efforts were devoted to refining production schedules, working more closely with those offices across the Institute which supply information, identifying inefficiencies and gaps in all aspects of "delivery" of the product to customers, and considering ways to enable (at least internal) customers to provide feedback about how well the office's publications met their needs. Identifying sources of

variability over which the office could exert some influence helped to reduce rework, inefficiencies, and delays. Individual goal setting, and periodic review of those goals, was another significant aspect of the quality improvement effort.

Second, the office added a publication to this year's roster, the 1992 Members of the Faculty, which followed the previous edition by only three years. The publication contains photographs of active faculty in the ranks of full, associate or assistant professor at MIT as of September 1991. The "picture book" was published on schedule and under budget.

Finally, the Communications Office negotiated a favorable new five-year contract with the vendor who prints the MIT faculty and staff, and student, telephone directories. The terms of the contract include profit-sharing and printing of both directories (24,000 copies) free of charge to the Institute.

Three major goals planned for next year are closely linked. First, the office's manager will continue to work as a change agent to promote total quality management principles in projects within Public Relations Services. This includes participation on the TQM task force, planning and helping to implement training support for staff, and documentation of progress made by initial working groups.

Second, the Communications Office will apply, and learn, the principles of total quality management by tackling the following projects: define the mission of the MIT Bulletin in the context of other Institute publications, survey its customers, and evaluate the extent to which the publication is successful in the work that it does. (Is information accurate and accessible? Does the Bulletin answer all the appropriate questions?) Acknowledging that the project is a long term effort, the office plans to work closely with Admissions and the Registrar to reevaluate the current publication and to develop and execute plans for the future.

Third, in conjunction with the Admissions Office, the Communications Office has identified an "architect of information" who could serve as a key advisor to individuals at MIT in the "information business," that is, individuals actively engaged in writing, editing, and publishing information for and about MIT. Through his lively and creative publications, this consultant, Richard Saul Wurman, has already helped to shape publishing plans in the two offices already involved. On the agenda for next year are joint efforts to rethink both the shape and content of current publications -- specifically, the MIT Bulletin and the Admissions' viewbook -- and to develop cross-functional (academic and administrative) working teams to implement change.

Personnel
The Communications Office successfully met this year's demanding schedule of publications because of enthusiastic and efficient teamwork. Members of the team, who have worked together for nearly two years, include manager Barrie Gleason, editor and production manager Ruth T. Davis, and senior office assistant Marianne Charny.

BARRIE GLEASON

OFFICE OF DESIGN SERVICES

The Office of Design Services continues to support the communications efforts of MIT by designing and managing the production of publications for departments and offices throughout the Institute. Among the areas receiving major assistance from the office during the past year were the Corporation, Resource Development, the School of Engineering, the Sloan School of Management, the School of Architecture and Planning, the School of Humanities and Social Science, the Medical Department, Public Relations Services, the Media Lab, and the MIT Museum.

Included among special projects and events this year were the MIT Inauguration Community Ball poster and invitations; the MIT Colloquium poster, "Teaching within a Research University;" the Margaret MacVicar Faculty Teaching Fellows Program; the Sloan School Alumni/ae Relations identity program; the

School of Humanities and Social Science newsletter; the Raytheon Lecture Series brochure and poster; the MIT Media Lab newsletter series; the MIT Museum Tech Group mailers; the MIT Developing Countries brochure; the Graduate Study for African-American Students brochure; the Reports of faculty committees on Academic Responsibility and International Relationships at MIT, and a redesigned Campus Map.

Overall, the Office undertook 285 graphic design and publishing projects in 1991-92.

In the computer area, numerous projects were produced on our electronic publishing system and coordinated through the collaborative efforts of Institute clients and our staff. Continued development of desktop publishing -- including the generic coding of manuscripts, new software programs, and providing color-separated film negatives to our printers for the first time -- enabled our office to streamline the production processes of many in-house publications.

Through the utilization of electronic publishing, the office continues to produce consistently high-quality design publications for the MIT community which are cost-effective, on schedule, and reflect the needs of the client. Typesetting costs have dropped significantly in the past few years, the production cycle is faster and shorter, which in turn has allowed our staff to be more flexible and accurate at an earlier stage in the design process.

As we continue to address the issue of a more comprehensive network system, our primary objective will be to expand our accessibility to major Institute clients, as well as establishing stronger communication links between internal offices, writers and outside vendors. With faster, more efficient computer upgrades for our group, staff requirements will be reviewed to include a design intern, a part-time production specialist, and possibly a Public Relations Services writer who could be available to work on projects that require special attention.

Several publications from our office received design awards this year: Elizabeth Chimento's book, "The Media Lab 5th Anniversary" was featured in the 1992 New England Book Show and Celia Metcalf's brochure, "Arts at MIT" will appear in Print's 1992 Regional Design Annual.

Personnel

The staff of Design Services during 1991-92 included Elizabeth Chimento, senior designer, Elizabeth Ferry, production manager, Anne Hubbard, senior designer and Lee McMahon, administrative assistant and production coordinator.

CELIA METCALF

INFORMATION CENTER AND SPECIAL EVENTS

The multiple mission of this office is to meet the informational needs of the MIT community, visitors to the campus, and the public; to promote a sense of community within MIT; to support conferences and events which enhance MIT's role in the broader academic community; and to support MIT's international community of scholars.

Information Center

The Center provides information in person and over the telephone to thousands of visitors and members of the MIT community each year. It supervises the campus tours; serves as a clearinghouse for mail addressed generally to MIT; maintains official Institute mailing lists; distributes some 40,000 publications; maintains records and publishes membership of faculty and presidential committees. This year the Center published a new, indexed, pocket-size campus map for use by visitors and the MIT community.

General tours of the Institute are conducted through the Center by MIT student guides who are members of an honor society. The tour guide captain, Christina H. S. Kwon, Course 7A, Class of '92, served as Head Guide -- training and scheduling 35 student guides to conduct tours for nearly 11,000 visitors this year.

Of these visitors, 3,671 were prospective students, 1,105 were international visitors, and 5,317 made up the remaining total. Full-time guides during the summer were Irene (Amy) A. Bany, Course IX, Class of '93, and Patricia L. Dunlavey, Course IV, Class of '93. There were 258 agency-sponsored international visitors who had their United States trips paid for by the United States government or private agencies in the United States, and 956 non-sponsored international visitors who were given special tours and/or had meetings set up with faculty and academic staff.

Special Events

Major special events this year included the celebration and opening of the Rotch Library, the Presidential Inaugural Ball, a birthday celebration for the Chairman of the Corporation, Dr. Paul E. Gray, the Killian Lecture by Professor Noam A. Chomsky, and the Commencement Exercises.

Commencement was preceded by the hooding ceremony for doctoral candidates. Rockwell Cage was filled to capacity with family and friends who came to share in this happy event for over 300 doctoral candidates. The following day, the Commencement ceremony was held indoors due to heavy rains -- the first time in the thirteen years since the ceremony was moved outdoors to Killian Court. Rockwell Cage was again the setting for the graduates, faculty, trustees and reunion classes to hear addresses by Congressman Les Aspin and President Charles M. Vest. The graduates then dispersed to three different locations to receive their diplomas in the company of their families and friends, and then all joined together for the President's reception in the Johnson Athletics Center. During the summer, a sub-group of the Commencement Committee will meet to review these "back-up" procedures and make recommendations for improved contingency plans for the future.

Goals for the coming year include participation in planning efforts to determine how best to meet the Institute's needs for conference and special events facilities. This includes surveying facilities at other universities and assessing the feasibility and desirability of including special events capabilities in the Central Athletics Facility now being planned.

International Scholars Office

Most government immigration regulations changed during the past year and substantial changes have been proposed for the year ahead. Immigration regulations go through an arduous process of advanced proposed rule making, and the International Scholars Office (ISO) responds to each phase of rule-making in an effort to safeguard the teaching and research activities of scholars visiting MIT.

The ISO served a total of 1,621 scholars during the past academic year, an increase of over 200 scholars coming to MIT over the previous year. There were 1,140 J-1 exchange visitors, 230 H-1 professionals in specialty occupations, 251 scholars in other visa categories, and 25 labor certification applications filed for permanent resident status. The population of scientists from the former Soviet Union has increased sharply during the past year with new immigration and personal issues confronting these scholars. Increased anxiety among scholars from the People's Republic of China is palpable, and again, their special needs require time and careful attention.

Of particular concern have been the new regulations concerning the H-1 visa for professionals in specialty occupations. We are in the process of deciding how best to respond to these regulations in the context of the Institute's policies and procedures.

Our newly-designed computerized database is in the final stages of fine tuning. This program is now being marketed to other universities who often seek our advice.

The office held two workshops on H-1 procedures for scholars and administrative staff, as well as a number of presentations at departmental staff meetings concerning procedures and regulations on hiring international scholars. This a more effective way to introduce the International Scholars Office and the immigration procedures, rather than at larger workshops. The office plans to ask other departments if they would like similar presentations at staff meetings.

ISO goals for the coming year include establishing a policy regarding the implementation of the new H-1B and J-1 visa regulations, formulating policies regarding visas for scholars from the People's Republic of China, and preparing the first of a major annual statistical report on international scholars at MIT.

Conference Services
The Office coordinated 26 conferences and meetings sponsored by MIT faculty and staff, which brought more than 5,000 visitors from all over the world to campus. In addition, the office handled arrangements for more that 115 recruitment presentations by companies and other organizations that visited MIT under the auspices of the Office of Career Services and Preprofessional Advising. This year, the office also enhanced many of the automated services (such as pre-registration procedures) available to clients. Goals for next year include participation in the feasibility study of conference and special events facilities, expansion of conference coordination services, with emphasis on consolidating the dormitory housing operation during the summer.

Personnel
While the Center said good-bye to some good friends and co-workers and wished them well in their new endeavors, we welcomed new members to our small staff of steadfast employees who deserve a special salute and a note of gratitude and appreciation. We especially congratulate Gayle M. Fitzgerald, who continued her heavy workload until two days before the birth of her son Andrew Paul in February.

MARY L. MORRISSEY

NEWS OFFICE
The Department of Justice suit against MIT alleging that the Institute's need-based financial aid policies violate the Sherman Antitrust Act was a major news development during the past year, along with the issue of the overhead cost of government-funded research. The News Office devoted a considerable part of its information and public relations resources to the support of the MIT response to these developments.

MIT's decision to fight the antitrust allegation in court was hailed in editorials in *The New York Times, The Washington Post, The Boston Globe, The Philadelphia Inquirer* and *The Los Angeles Times.* As the year ended, MIT was in Federal Court in Philadelphia, defending itself against the unprecedented effort to apply the antitrust statutes to the educational activities of a nonprofit organization.

The News Office worked closely with the Institute administration and MIT's law firm in developing material for reporters that explained our commitment to need-blind admissions.

MIT Tech Talk—37 issues were published this past year—played a major role in this effort. Many articles that originally appeared in this paper, where they kept the MIT community abreast of developments, were repackaged into special reprints and press releases that carried MIT's views on the subject to reporters, columnists and editorial writers.

In addition, a special January issue of *MIT Tech Talk* was devoted to the overhead cost controversy and received wide distribution.

During the year just ended the News Office issued more than 150 news releases on a variety of subjects. Many of them were illustrated. We have found that illustrating news releases increases the frequency with which the material is "picked up" by a news outlet.

We introduced in December a new publication, the MIT Research Digest -- a monthly, illustrated, double-sided sheet, each issue containing 7 to 10 news briefs on research. The goal: to interest science reporters to do in-depth articles on the projects. Initial results are favorable and we plan to continue the project.

A pleasing development during the last 12 months was the attention given MIT by news outlets in the Institute's own back yard, two examples being a *Boston Sunday Globe Magazine* cover story that profiled

MIT and Harvard and a 30-minute program entirely devoted to MIT on WCVB-TV's popular Chronicle program.

Another important development during the year was the cooperation of MIT and WHDH-TV, Channel 7, in what will be a series of programs aimed at increasing interest in science and math among students in the K-12 grades.

MIT, its people and their research continued to be mentioned frequently in articles and broadcasts. Subjects ranged from the discovery of chemical abnormalities unique to the brains of Alzheimer's victims to how new luxury boxes built atop Fenway Park have changed wind currents, costing the Red Sox some home runs.

Our goals for the year ahead include increasing the number of 12-page issues of MIT Tech Talk, which will permit us to publish a greater variety of information for the community; increasing our science news coverage in *MIT Tech Talk* and our outreach to science reporters; and developing, in cooperation with Video Production Services, a store of videos about MIT with a news and public relations focus.

Personnel

Major contributions to New Office undertakings were made by our support staff, headed by Myles P. Crowley, administrative assistant to the director; Lisa Damtoft, senior staff assistant, and Chandra L. Wilds, receptionist.

The administrative staff working with Director Kenneth D. Campbell and Associate Director Robert C. Di Iorio included: Charles H. Ball, senior assistant director; Naomi F. Chase, assistant director/public relations; Donna M. Coveney, assistant director/photojournalist; Joanne Miller, assistant director/editor-*MIT Tech Talk*; and Elizabeth A. Thomson, assistant editor-*MIT Tech Talk*.

No account of News Office activities during the past year would be complete without mentioning the emergence of the office softball team, The Clippers, as a force to be reckoned with. The Clippers play in the MIT Summer Softball Kentucky Fried Chicken League (Extra Crispy Division.) And we're finger lickin' good.

KENNETH D. CAMPBELL

VICE PRESIDENT FOR FINANCIAL OPERATIONS

The Institute used $6.8 million of unrestricted gifts, grants, and bequests and $6.3 million of other funds to balance the Fiscal 1992 operating budget. The $6.3 million was from a series of current fund and earned income on various reserves. No funds functioning as endowment were used in operations. No funds functioning as endowment have been expended by MIT since Fiscal 1982.

MIT had modest surpluses in the operating budget in Fiscal 1984-1988, and modest deficits in Fiscal 1989-1992. We will remain in a deficit pattern in future years unless efforts are made to reduce expenses. There is continuing pressure on the operating budget from resource constraints as MIT attempts to maintain its academic excellence and pursue new opportunities. It is difficult to meet all objectives of reasonable growth in tuition and self-help levels, competitive salaries for faculty and staff, and need-blind admissions. Despite efforts to control costs, there are both unexpected and necessary Institute-related events that add to the imbalance in the operating budget. Recent examples include: legal fees, less than full indirect cost recovery, and undergraduate financial aid. As well, the budget forecast contains many assumptions that add to the risk of achieving a balance between current expenses and revenues.

We must bring the operating budget into balance. It is appropriate in view of the financial constraints facing MIT, particularly relating to decreasing research funding and support, to begin the planning to achieve constructive reduction in expenses as well as properly develop the central and departmental administrative structure for the future. This planning has already begun under the auspices of the President, Provost and Senior Vice President.

Despite the need to reduce expenses in the operating budget, it is important to note the underlying financial strength of the Institute as restricted academic funds continued to grow from endowment income that is not spent, and as many gifts, which have increased significantly as a result of the success of the *Campaign for the future*, flow into current funds or endowment funds.

The imbalance in operating revenues and expenses continues to require judicial and well-planned implementation of cost containment measures in both academic and support programs and continued rigorous budget control exercised by the President, Provost and other Senior Officers for the areas in which they have management responsibility. A large portion of the burden in reporting and managing this cost control rests with the Financial Operations area. Again this year the events in the area of audit and financial review have necessitated efforts by many members of Financial Operations well beyond their normal responsibilities. These extra efforts are very much appreciated by all members of the MIT community.

At the same time, a number of new programs and systems have been introduced to streamline operations and increase efficiency in financial control and reporting. The reports that follow highlight these and other activities of the last year in the five major areas of Financial Operations.

The reports of each department highlight the major activity that has occurred during the year. While they describe many of the activities, they cannot adequately express the amount of care and effort of Financial Operations staff to ensure that the finances of MIT continue to be effectively managed. I extend my sincere appreciation to all members of Financial Operations for their outstanding efforts.

AFFIRMATIVE ACTION EFFORTS IN FINANCIAL OPERATIONS AREA

Increasing the numbers of women and minorities in career positions continues to be a major goal of the area. Every search plan and appointment to the Administrative Staff is reviewed by the five area department heads, with final approval, on their advice and consent, by the Vice President. This procedure has been effective in keeping affirmative action efforts a priority on a weekly basis. this attention has had good results in the hiring and promotion of women and minorities. We must, however, continue these efforts as a major priority of the area.

As of June 30, 1992, the total number of women administrative staff is 103 (43%), while underrepresented minorities are 19 (8%) of the Administrative Staff of 240. (In 1991, these figures were 99 (43%) and 18 (8%) of 228, respectively.)

Including support and service staff members, the number of underrepresented minorities is 49 (12%) of a total staff of 422. (In 1991, the figure was 47 (11%) of 414.)

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 45 (37%) out of a total administrative staff of 122. (In 1991, the figure was 43 (36%) out of a total of 118.)

The number of underrepresented minorities is 18 (8%) out of a total staff of 216. (In 1991, the figure was 19 (9%) out of 216.)

Office of Financial Planning and Management
The number of women administrative staff members is 5 (42%) out of a total administrative staff of 12. (In 1991, the figure was 6 (46%) out of 13.)

The number of underrepresented minorities is 1 (8%) out of a total staff of 13. (In 1991, the figure was 1 (7%) out of 14.)

Office of Purchasing and Stores
The number of women administrative staff members is 9 (30%) out of a total administrative staff of 30. (In 1991 the figure was 8 (31%) out of 26.)

The number of underrepresented minorities is 11 (15%) out of a total staff of 75. (In 1991, the figure was 11 (15%) out of 73.)

Office of Registration and Student Financial Services
The number of women administrative staff members is 37 (73%) out of a total administrative staff of 51. (In 1991, the figure was 34 (74%) out of 46.)

The number of underrepresented minorities is 16 (20%) out of a total staff of 81. (In 1991, the figure was 13 (17.5%) out of 74.)

Office of Sponsored Programs
The number of women administrative staff members is 7 (39%) out of a total administrative staff of 18. (In 1991, the figure was 7 (39%) out of 18.)

The number of underrepresented minorities is 3 (10%) out of a total staff of 30. (In 1991, the figure was 3 (10%) out of 30.)

JAMES J. CULLITON

Payroll

During the past year two major modifications were introduced to the Payroll System. An enhancement to automatically cease tax deferred deductions/reductions was implemented to provide more timely and accurate compliance with federal regulations. Also, an electronic Time Reporting System was provided to the MIT community for the Service Staff, Support Staff, and MIT Student Payrolls.

In addition, considerable resources were devoted to the maintenance of the system to maintain industry level standards and to comply with the usual tax reporting modifications which have become a significant annual task.

Financial Systems

Significant enhancements continue to be made to the General Ledger System to reduce the time required to produce accounting statements and provide the MIT community with timely and accurate information. Major enhancements were made to the Investment System which enabled the Treasurer's Office to accrue life income on a calendar basis as well as a fiscal basis. IDS custom security pricing was installed on the Investment System saving many hours of manual pricing. To help improve information gathering for the Purchasing System, the size of the reference number was increased. While this may seem to be a minor event, it required involved planning and careful implementation due to the complexity and extent of the Financial System which interacts with many other systems. This year, due to complex changes in Internal Revenue Service (IRS) reporting and facing a steep increase in price by the vendor which produced our 1099 Forms, we were required to produce our own 1099 Forms and IRS reporting; and, by doing this, we were afforded the opportunity to gain greater control and more timely reporting as well as reducing the cost to MIT. Development of a new Cashiering System has been started. This system will replace the current system which has been outpaced by current technology. The new system will provide increased reliability and data integrity as well as better service and system management. All financial systems were successfully moved to the new IBM computer. Enhancements continue to improve the Journal Voucher, Accounts Payable, and Accounts Receivable Systems; provide better service to the MIT community; and provide more information to manage these functions more efficiently.

Benefit Accounting

The Benefit Accounting Office was reorganized into several functional areas in an effort to improve service to the MIT Community. The newly created areas are: Accounting and Finance; Health, Dental and Life Insurance; Pension Payroll and Retirements; and Pension Plan Administration. The procedure for paying cost-of-living increases to MIT retirees was automated and incorporated with the Pension Payroll. Significant changes were required for reporting annual tax related data to the IRS. Form W2-P was discontinued by the IRS and all payments were reported on tax Form 1099R. In the health related area, approximately 1,500 subscribers of MIT's Medicare Supplement plans who were eligible for a refund of premium as a result of changes in federal laws were identified and provided with refunds. To simplify the flow of benefit forms and to eliminate duplication of effort, the Benefit Accounting Office assumed responsibility for keying support and service staff tax deferred annuities, data entry for campus FRAP for all payroll categories, and maintenance of all benefit forms for Comptroller's Accounting Office support staff employees. Also, the calculation of imputed income on life insurance for MIT retirees became an automated procedure.

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, 10,672 newly acquired items of moveable equipment were identified and tagged. The biennial inventory of items of moveable equipment was completed. Two hundred thirty-one final inventories were submitted as part of closing out the contracts, grants, and agreements, etc. There were 514 financial reports prepared and submitted to various government agencies. One hundred ninety-four

part of a reutilization program. Equipment, unneeded or unusable by the MIT Community, was sold for $133,000 providing funds for replacement equipment.

Release 2 of the new Property Inventory and Accounting System is in its final development stage.

The Society for Property Administrators, which is administered by the Property Office, conducted five one-day Property Management Workshops at different universities around the country.

LINCOLN FISCAL OFFICE

In July 1991, the Lincoln Fiscal Office (LFO) upgraded to an IBM AS/400, Model D70, greatly increasing its computer capacity throughout the laboratory to the Institute. With the elimination of Lincoln Laboratory's central computer facility in September 1991, the LFOINFO Management Information System was moved to the campus "A" machine. Access from the laboratory is accomplished either through the AS/400 or direct telephone line. Plans are being formulated to establish a network link.

The Property Section of the LFO is presently testing and defining a Bar Code Scanning System. This is expected to enhance the efficiency and control of the perpetual inventory of over 75,000 items of property numbered equipment. Over $5 million in government surplus capital equipment was acquired over the fiscal year. Other materials and supplies are being obtained from government surplus listings on a regular basis.

THE AUDIT DIVISION

The Audit Division continues to render service to 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. Audit efforts both on campus and at Lincoln Laboratory have been further enhanced with the adoption of a Quality Assurance Program formulated in accordance with the Standards for the Professional Practice of Internal Auditing,promulgated by the Institute of Internal Auditors.

Federal Government audit activity has never been more intense than this past year with the controversy over indirect costs. The Audit Division has been working closely with the Comptroller's Accounting Office to address indirect cost issues and work toward timely resolution. The Office of Management and Budget (OMB) Circular A-21, "Cost Principles for Educational Institutions," was formally revised in October 1991 to more clearly delineate unallowable direct and indirect charges to federal grants and contracts.

One major accomplishment in the past year has been the completion of the Audit Division's first Institute-wide cycle of departmental reviews. Over the past four years, each department, laboratory, and center was visited in order to examine the degree of compliance with Institute and federal guidelines relating to proper account monitoring, certification of effort, record retention, and other control issues. Based upon follow-up efforts, it appears that, in most instances, timely and appropriate action has been taken to correct reported compliance and control deficiencies. A new departmental review cycle will begin this year to address new compliance and control issues as well as re-examine critical areas included in the earlier review effort.

Audit Division involvement in Information Systems continues to broaden as new systems are developed and new technologies emerge. In particular, Institute efforts to reduce reliance on paper records by creating, transmitting, and maintaining data electronically will depend upon our ability to ensure the integrity and reliability of internal controls over associated information systems and data. Federal record retention requirements and standards for electronic record keeping are also factors which will dictate how MIT addresses electronic records management.

Internal audit coverage is coordinated with the Institute's Certified Public Accounting firm, Coopers & Lybrand, and MIT's federal cognizant audit agency, the Defense Contract Audit Agency. With the implementation of the OMB Circular A-133, "Audits of Institutions of Higher Education and other Non-Profit Organizations," coordination between the various audit entities has become much more formalized as the circular calls for an organization-wide audit utilizing a fully coordinated audit approach..

Personnel Changes

The following staff changes occurred within the Comptroller's Office during the past year:

New Appointments

Darlene M. Masefield
Auditor I

Promotional Appointments

Maria C. DiMauro
Property Auditor

John W. Erkkila
Property Auditor

Kenneth F. LeVie, Jr.
Staff Accountant

Promotions

Robert N. Clark, Jr.
Audit Manager

Robert M. Damian
Assistant Accounting Officer

Mary T. Donovan
Analyst/Programmer III

Suzanna Garfunkel
Analyst/Programmer III

Carol J. Gleason
Assistant Accounting Officer

Michael J. Glynn
Analyst/Programmer III

David F. Goodwin
Senior Staff Accountant

Ann M. Langton
Senior Accounting Officer

Douglas J. LeVie
Senior Staff Accountant

Diane R. Monahan
Data Base Manager

Denis W. Shield
Analyst/Programmer III

Carl P. Whitaker
Assistant Accounting Officer

PHILIP J. KEOHAN

Office of Financial Planning and Management

FISCAL 1992 RESULTS OF OPERATIONS

The Institute's operating budget is planned to essentially break even, with small surpluses or deficits occurring each year. In this context surpluses mean additions to reserves and deficits mean use of reserves to balance operations. In the last decade there have been five surplus years and five deficit years. Since tuition rates are set months in advance of the beginning of a fiscal year, and major portions of our other revenues are subject to the vagaries of the economy and government appropriations, the accurate prediction of revenues is risky. The budgeting of expenses is far more stable with the exception of utilities and a few other items that are outside our control. Despite these uncertainties none of the operating surpluses or deficits in the last decade have exceeded one percent of total expenses. The Institute, over its 131 year existence, has established unrestricted reserves that provide the ability to absorb deficits.

Total operating expenses for the year were $1,081 million - down 0.4 percent from the previous year. Total operating revenues were down 0.9 percent to $1,075 million leaving a deficit of $6.3 million after the use of all unrestricted gifts. The deficit was funded by the use of earned income on reserves accumulated from the current and prior years. The original projected deficit reported to the Executive Committee in May of 1991 was $4.0 million. This deficit was revised upward to $4.1 million in reports to the Executive Committee in subsequent months, and modified to $6.3 million at financial closing. The net change in the deficit of $2.2 million was comprised of adverse effects of $9.7 million and positive effects of $7.5 million.

Four major adverse effects increased the deficit by $9.7 million. These included a decrease in indirect cost recovery revenues ($3.5 million), an increase in undergraduate student aid ($3.2 million), lower tuition revenues than budgeted ($1.8 million), and a one time increase in employee benefits ($1.2 million).

Two major positive effects provided a $7.5 million offset to the adverse effects. These included significant department and Institutional expense and carry-forward control ($5.6 million), and the availability of fund balances from prior year's gifts and income ($1.9 million).

It is important to note that modest surpluses or deficits in operations do not convey the underlying financial strength of MIT. A better measure of this strength is found in the growth of the Institute's fund balances. These balances, net of borrowing, have increased by a total of $675 million over the last five years, or an average of $135 million per year. The book value of the Institute's fund balances was $1,758,998,000 as of June 30, 1992.

FINANCIAL PLANNING

The Executive Committee of the Corporation approves and monitors a four-year fiscal plan covering the current fiscal year and three years into the future. The current year portion of the plan is based on detailed budgets submitted by each of the Institute's departments. The responsibility for controlling expenditures within an account rests with the supervisor of the account, usually a faculty member or department head. Monthly account statements are issued which show both budget and actual charges. These accounts are monitored not only by the supervisor, but by the department head who has overall responsibility for the accounts within the department. Certain expenses are controlled centrally to assure conformance with the Institute's fiscal policy, contractual obligations to program sponsors or the donor restrictions. The Executive Committee continually reviews the fiscal plan, and any change to the plan requiring unrestricted funds in excess of $25,000 must be approved by the Executive Committee.

As mentioned above, the Institute has reserves that are available to support its programs in deficit years. However, financial trends that indicate a long term erosion of reserves call for budget review and measures to bring the operating budget into balance. The Institute now faces financial constraints, particularly those relating to research funding and support, that will require our attention and action in the coming fiscal years as we adjust to new patterns of funding and other constraints.

CAPITAL BUDGET

At the end of the year the Institute's capital and major renovations budget was $482 million. The project budgets include $395 million for 13 active projects and $87 million for 6 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 $245 million for the active projects and $65 million for the future projects. The interest portion of the budget is estimated at $139 million and will extend from ten to thirty years, depending on the project.

The book value of the educational plant assets was $347,172,000 at June 30, 1992 up from $327,591,000 at June 30, 1991.

The addition of 6,600 square feet of new construction and the renovation of existing space at the Haystack Observatory in Westford, Massachusetts was completed during the year. Excavation and construction of the foundation for the new Biology Building at 31 Ames street continues as does the renovation of the building at 38 Memorial Drive to academic uses continues. This building will be used by the Sloan School of Management and the Dibner Institute.

On August 27, 1991 the Institute sold $25 million of tax exempt Multi-Modal Variable Rate Demand bonds through the Massachusetts Health and Educational Facilities Authority. These bonds sold initially at 4.4 percent interest in a seven day variable rate mode. Provisions of the Loan and Trust agreement allow the Institute to convert the bonds to a Daily, Flexible, Weekly, Multi-annual, or fixed rate modes. The bonds are subject to tender by the bondholders. Throughout the year the issue has been held in the Weekly mode. The acceptance of the bonds by the financial community was evident by the competitive rates the bonds received at the weekly determination of rate as compared to other similar institutions and market indicators.

Total mortgage indebtedness for educational plant at June 30, 1992 was $102,971,000 of which $84,972,000 is tax-exempt debt financed through the Massachusetts Health and Educational Facilities Authority.

FINANCIAL SYSTEMS

During 1991-1992 we continued the enhancement and expansion of the OFPM database and systems. This year we concentrated on development of system components to broaden our data population and to increase our flexibility to provide pertinent and timely management information to Institute senior officers. Specifically, we developed capability for interpreting research budgets and expenses. This facilitates both our internal evaluation of research trends, and our ability to respond to external requests for information. We also established a reporting structure to consolidate and monitor budgets for administrative computing expenses. This information is used by the ACSC (Administrative Computing Steering Committee) and the ACRM (Administrative Computing Resource Management) Committee. The major enhancement during the year was the development and population of a comprehensive historical database. This database includes dollar and people information for fiscal years 1976 through 1992, and has been defined to reclassify operating units to conform with the current organizational structure.

PERSONNEL AND ORGANIZATION

The breadth of the office's mission provides a source of well trained staff for other departments and laboratories at MIT. This year was no exception as Junco Norton transferred to the Sloan School to help with their financial administration. Leslie Mulford left MIT to join her husband in France. She was replaced by Eileen Francis who will continue the work Leslie did on the Capital Budget. Eileen brings with her extensive experience in public and non profit financing.

JOHN A. CURRIE

Major projects accomplished or initiated this year include:

(1) **EREQ System**

EREQ is the Institute's on-line and interactive electronic requisitioning system. EREQ was approved and funded by the Administrative Computing Steering Committee and developed by the Office of Purchasing and Stores.

EREQ is a free service, available to all members of the MIT community.

By year's end, the EREQ system had been expanded to support five major functions:

- **Electronic Requisitioning to Purchasing.** Users are able to create and instantly forward requisitions which do not exceed $5,000 in value to the General Purchasing Office for review and purchase order issuance, usually within two hours.

- **Electronic Speed Orders.** If the value of an electronic requisition to Purchasing is $500 or less, the user is able to specify the immediate assignment, on-line, of a purchase order number which he/she can promptly relay to the vendor.

- **Electronic Requisitioning to Office of Laboratory Supplies.** Users are able to create and instantly forward requisitions to the Office of Laboratory Supplies for order filling and delivery, usually the next day.

- **Electronic Requisitioning to Internal Providers** . Users are able to create and instantly forward requisitions to MIT departments, laboratories, and centers that are suppliers of goods and/or services for internal use.

- **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 databases.

When electronic requisitioning to Internal Providers was added to the EREQ system in June, EREQ users could create and forward electronic requisitions to:

- **MIT Catering** - for food requirements for meetings and special events.

- **Telecommunications** - for telephone services - add a phone, add features, et cetera.

During July and August of the coming year, the following MIT departments and laboratories will also become EREQ system Internal Providers:

- **Physical Plant** - for specialized services - carpentry, electrical, locksmith, moving, et cetera.

- **Graphic Arts, Quick Copy Centers, and Audio Visual Service** - for the printing, copying, and audio visual services these offices provide.

- **Supercomputer Facility** - for use of Cray supercomputer time.

- **Cryogenic Engineering Lab** - for liquid nitrogen and liquid and gaseous helium.

During the coming year, we expect that a number of other MIT departments, laboratories, and centers will also become EREQ system Internal Providers.

EREQ was introduced to the MIT community in May 1990, at which time we commenced an ongoing program of user training and implementation of the new system. By June of this year, over 1,100 Institute requisitioners and administrators had become EREQ users. (A base of 4,000 eventual users is projected.) Use of the EREQ system increased significantly throughout this year. During the month of June, users logged-on to the system over 6,000 times, generating over 13,000 independent transactions to view the status of their business and to create 3,000 electronic requisitions and speed orders.

(2) **EREQ Routing System**

Development of an electronic routing system for EREQ was approved and funded by the Administrative Computing Steering Committee in January of the previous year. Completion of this major development effort and system implementation is scheduled for spring 1993. A prototype of the system was installed this year for test purposes using "live" electronic requisitions in five user departments and laboratories. Additional user test locations will be added during the summer and fall of the coming year.

The EREQ Routing System will dramatically speed the processing of requisitions as it will enable routing requisitions electronically for on-line reviews and approvals (i) to account supervisors, account addressees, and central fiscal offices, as required and as may be stipulated for each account number; (ii) to other administrative offices as required by MIT policies and procedures and federal contract and grant regulations; and finally (iii) to any purchasing location on campus, to the Office of Laboratory Supplies, or to any Internal Provider for requisition fulfillment.

Electronic routing is also necessary because the EREQ system automatically limits user access and privileges to the account numbers and dollar levels which the user's account supervisor has authorized (by granting formal signature authorization). Therefore, individuals with no signature authority are unable to create electronic requisitions, and individuals with low signature authority can only create electronic requisitions which total no more than their dollar level of signature authority. Electronic routing will eliminate these restrictions.

(3) **VAPS System Upgrade**

In January, the Administrative Computing Steering Committee approved our proposal to upgrade the VAPS (VAX 8550 computer system for Accounts Payable and Purchasing) to extend its useful life. This upgrade, which commenced this year and will be completed during the summer of the coming year, will extend the computer's useful life into 1994. A proposal to replace the then seven year old computer will be submitted, in the coming year, to the Administrative Computing Steering Committee.

(4) **Government Approved Procurement System**

Representatives of the Office of Naval Research and the Defense Contract Audit Agency conducted the sixth review since 1976 of the Institute's procurement system. The Review Team was highly complimentary of the Institute's procurement procedures and practices, and, as a result, the Office of Naval Research will provide formal notification early next year that the Institute's "Government Approved Procurement System" will be continued.

General Purchasing Office

A major effort this year has been the continued promotion and support of the EREQ system, on a person-to-person basis and through visitations to high volume requisitioning departments and laboratories.

EREQ continued to have a major impact as the number of low dollar requisitions which have been eliminated from the office workload due to the popularity of EREQ's Electronic Speed Order function increased substantially. As a result, the staff of the office was again reduced by 10 percent. To date, the office staff has been reduced 20 percent as the direct result of EREQ.

Other purchasing activity continued at a high level. Of a total 74,000 purchase orders issued by all on campus purchasing agencies (94,000 purchase orders issued, less 20,000 of which were electronic speed orders issued by EREQ users), the General Purchasing Office processed and issued 44,000 or 59 percent of the total.

Since the primary responsibility of the 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 processed and filled 79,000 requisitions containing 240,000 line items of supplies, tools, devices, and furniture and furnishings.

Combined sales of office and laboratory items and furniture and furnishings decreased 0.3 percent compared to the previous year. Sales of office and laboratory supplies increased 0.5 percent and sales of furniture and furnishings decreased 1.8 percent.

Arrangements have been completed to provide for the relocation of the administration and warehouse personnel and activities of the office to 350 Brookline Street, Cambridge during the fall or winter of the coming year. This is advantageous, as valuable campus space will be freed-up in buildings 4 and N52 for academic use and the office will gain long-needed, ample warehouse and receiving space and facilities. Stockroom personnel and facilities will remain in their current on campus locations.

Minority and Woman-Owned Business Purchasing Programs

Business placed Institute-wide under these affirmative action procurement programs resulted in the award of $15.6 million to minority and woman-owned business concerns. This represents an increase of 5.5 percent over last year's accomplishments. Over $7.3 million was awarded to over 400 minority businesses and over $8.2 million was awarded to over 900 woman-owned businesses.

Subcontracting Plans under Federal Contracts

Subcontracting Plans are required (by law) for each contract proposal to a federal agency which exceeds $500,000. The Subcontracting Plan specifically identifies the efforts that will be undertaken under a resulting contract to assure the award of a fair proportion of subcontract and purchasing dollars to small business concerns and small minority business concerns. The Subcontracting Plan includes both dollar and percentage goals which are negotiated with the sponsor and become a material part of the resulting contract.

As a service to departments, laboratories, and centers, the Assistant Director for Subcontracting and Government Relations coordinates with the Office of Sponsored Programs and principal investigators, prepares Subcontracting Plans for submission, negotiates changes when necessary, and reports accomplishments to federal sponsors and principal investigators. This year there were 50 active Subcontracting Plans under Institute federal contracts which necessitated the submission of over 100 separate reports of accomplishments to federal sponsors. Additionally, in order to provide guidance and assistance to principal investigators, over 100 internal progress reports were issued.

There have been indications that Subcontracting Plan requirements may be extended to federal grants also. In this event, the workload in this area will more than double.

BARRY ROWE

Office of Registration and Student Financial Services

Several significant events can be recorded for the past year.

In the Bursar's Office, the trend toward lower default rates in the Perkins/National Direct Student Loan Program continues. MIT's rate was 0.7 percent in 1991, compared with 1.2 percent in 1990; the national default rate for that program decreased from 6.2 to 6.0 percent in that period. Our default rate on Stafford Student Loans increased slightly to 2.3 percent in 1991, compared with 1.8 percent in 1990 (it was 2.2 percent in 1989); the corresponding national default rate was 15.5 percent in 1990.

Further, a landmark was reached when, for the first time, none of our students expecting to receive a degree in June was denied that event for financial reasons. Although we expected that the nation's economic woes would be reflected in an increase in that number (usually about ten), extraordinarily effective cooperative efforts with the Registrar's Office, the Student Financial Aid Office, and the Deans' and departmental offices, led by the Bursar's Office, produced this welcome and remarkable result.

In the Registrar's Office, major efforts continue in the development of the new Student Information System (SIS) authorized by the Administrative Systems Steering Committee two years ago. This project was undertaken so that we could replace the existing batch SIS (now about 20 years old) with an on-line, full-featured system in a relational database environment. During the Systems Architecture phase of this development plan, nearly completed during the period covered by this report, a series of training sessions on SCT's Banner system and the new DEC VAX was conducted for a core group of SIS users, and substantial progress was made developing an SIS functional process model, defining in detail the specifications of the new system from the user's perspective. The fourth, or System Construction, phase was begun as scheduled in March, and, as part of that phase, final contracts for substantial technical programming support, and for necessary peripheral software were negotiated—the first of these with SQL Solutions. The final, or Implementation, phase should begin, as scheduled, in January of 1993.

In the Student Financial Aid Office, the nation's sick economy had an appreciable effect on our need for unrestricted funds to meet our grant commitment to undergraduates. The actual aggregate financial need of these students exceeded our predictions by about $235K, as we experienced, much more frequently than is usual, appeals from our students as a consequence of diminished or loss of family income. And, on the income side, we realized a very significant decline in current gifts of about 40%, or about $610K below our $1,470K projection. These were the two major factors contributing to an overall shortfall of $1,080K in additional unrestricted funds necessary to support the financial aid program in FY'92.

After more than a year of pretrial preparations, the justice department's civil suit against MIT's financial aid practices went to court late in June. The substance of the justice department's argument was that the Sherman Anti-Trust Act is violated by MIT's agreement with other schools (notably the Ivy League) to award our own grant and scholarship dollars on the basis of students' financial need rather than on a competitive, merit-oriented basis. MIT founded its rebuttal arguments on the assertion that the charitable grants of a non-profit educational institution are not commercial activity covered by the Sherman Act; and proceeded to build the case that our aid policy clearly is in the public's best interest and furthers the important national goals of equal access to education for all qualified aspirants. The Associate Director of Student Financial Aid, Stanley Hudson, was one of MIT's witnesses, and strongly defended the Institute's policies as right and effective. A thorough review of the roots of the government's complaint, and MIT's response, was published in the *Tech Talk* on July 15, 1992. A verdict in the case is expected in September.

I close by sadly noting the retirement after 25 years at MIT of my close colleague, our Director of the Student Financial Aid Office, Len Gallagher '54. I, and we, shall miss him greatly.

We are fortunate indeed to announce that Stanley Hudson has been promoted to succeed Mr. Gallagher, and will become the SFAO's new Director on July 1, 1992.

These events and accomplishments are discussed in further detail, and others reported, in the individual reports that follow from the Bursar, Registrar, and the Director of Student Financial Aid.

JACK H. FRAILEY, DIRECTOR

BURSAR'S OFFICE

This was the first year we all recall in which there were *no* Bursar's Office *financial holds* of students planning to graduate in June! We expected the number to be greater than usual because of the economy, but cooperative efforts with the Registrar's Office, the Student Financial Aid Office, and Dean's and departmental offices, yielded this happy result.

This year we improved the technology which supports our operations. The two most significant improvements were:

In response to concerns expressed by the Treasurer's Office, we analyzed our operations and changed the bank we use for student accounts lockbox services, to better protect and more quickly receive $60 million in Institute funds and to improve technology for compatibility with the new Student Information System.

In Fiscal Year 92, we implemented electronic funds transfer for $5 million of Stafford Student Loans coming into 1800 MIT student accounts from Massachusetts banks. This service is valuable to MIT and to students. The Institute has these funds available for use immediately and students do not stand in line to sign checks.

Alumni Services

We provided support to the Sloan School's Leaders for Manufacturing program to set up a forgivable loan program.

We revised the legal document we use to contract for outside collection services, with the help of Palmer and Dodge.

Working with the Student Financial Aid Office, we implemented improved procedures for short term loans, to reduce the amount of "red tape."

Student loans receivable totaled $51,295,841 at fiscal year end. These notes were funded by $13,222,993 of MIT loan funds established by friends and alumni of the Institute; $26,730,358 of federal funds in support of the Perkins Loan Program; $8,242,490 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 0.7 percent in 1991 (compared to 1.2 percent in 1990); the national default rate for that program decreased from 6.2 percent in 1990 to 6.0 percent in 1991. MIT's default rate on Stafford Student Loans was 2.3 percent in 1991 (compared to 1.8 percent in 1990); the corresponding national default rate was 15.5 percent in 1990.

Financial Systems

We have improved significantly our "in house" ability to solve computer problems and to provide improved computer support to our office functions. Examples include programming to implement electronic funds transfer, and improvements in virus protection, backup procedures, software copyright compliance, and data transfer between systems (student information system to Wachovia, student information system and Wachovia to Macintosh network).

We have made use of new technologies made available to us by other offices, performing requisition, journal voucher, and payroll tasks electronically.

We have made use of new cartridge media for data storage and retrieval, which will conserve our scarce storage space.

Student Services

We have attended extensive on-campus training sessions on the new SCT systems (Banner and Financial Aid) and two SCT user meetings (national meeting in Atlantic City and regional meeting in Waltham).

We implemented printing of student bills on a laser printer, which gives us greater flexibility in changing bill format and in scheduling production.

Working with Student Financial Aid Office, we implemented a new Class of 1950 loan program to fully subsidize interest on Parent Loan Plan for alumni.

Student tuition, fees, and other charges totaling $187,392,019 were billed, an increase of 7.8 percent from last year. Servicing the 21,959 student accounts required 204,787 transactions to the student accounts receivable system. The amount collected as a percentage of the total receivable was 96.9 percent. Income from late payment fees was $157,619; income from finance charges was $164,699.

There were 244 active Parent Loan Plan accounts, of which 38 were new borrowers this year. A total of $1,345,015 was disbursed during the year and $1,289,106 in principal was collected. The PLP receivable at the end of the fiscal year was $1,421,996. The default rate for the Parent Loan Plan (calculated as of June 30, 1992 using the formula for NDSL/Perkins Loans) is 0.6 percent.

The total student population supported by a sponsor (government, military, etc.) for the academic year 1991-92 was 621 students, representing total billings to sponsors of $9,329,271.

Staff Notes

Cross-training sessions within our office have helped new staff provide continuity of service during a period of extensive turnover. We have put into practice our philosophy of upward job mobility through development and training, followed by promotion. (Six staff members were promoted within the Bursar's Office this year.)

We had four guest speakers at staff meetings: Sergeant Cheryl Vossmer (security); Professor Mary Rowe (work environment); Associate Dean Milena Levak (culture shock faced by international students); and Assistant Dean Ayida Mthembu (cultural diversity).

Cheryl Blankenship served on MIT's Task Force on Career Development for Minority Administrators and received the "YMCA Black Achiever Award". She also presented a speech, with Director of Student Financial Aid Stanley Hudson, entitled "The Staff Meeting- Campus Departments Working Together" for the Massachusetts Higher Education Assistance Organization student loan conference. Shirley

Picardi served on the SHARE Loan Advisory Board of the Consortium for Financing Higher Education. Kate Wilson served as Legislative Chair of Coalition of Higher Education Assistance Organizations.

Carolyn Bunker and Sandra Chauncey served as readers of undergraduate applications for the Admissions Office. Shirley Picardi and Ann Reilly served as academic advisors to freshmen.

The following changes in staff occurred:

Mary Barry was promoted in August from Senior Office Assistant to Assistant to the Bursar/Student Services.

Valerie Bryce was promoted in April from Administrative Assistant to Assistant to the Bursar/Student Services.

Janet Fischer, Assistant to the Bursar/Student Services, left in August to become Student Administrator in the Department of Chemical Engineering.

Suzanne Gilfoil was promoted in September from Senior Office Assistant to Assistant to the Bursar/Financial Systems.

Mary Jo Murray was promoted in August from Administrative Assistant to Assistant to the Bursar/Student Services.

Sue Wang, Assistant to the Bursar/Student Services, left in August for a position in career counseling at Wellesley College, her alma mater.

SHIRLEY PICARDI, BURSAR

REGISTRAR'S OFFICE

Registration

In 1991-92 student enrollment was 9,541, compared with 9,628 in 1990-91. This total was comprised of 4,325 undergraduates (compared with 4,389 the previous year), and 5,216 graduate students (compared with 5,239 the previous year). The International student population was 2,117, representing nine percent of the undergraduate and 33 percent of the graduate populations. These students were citizens of 103 countries. Students with permanent residence status are included with U.S. citizens.

In 1991-92, there were 2,589 women students (1,433 undergraduate and 1,156 graduate) at the Institute, compared with 2,593 (1,451 undergraduate and 1,142 graduate) in 1990-91. In September 1991, 368 first-year women entered MIT, representing 35 percent of the freshman class of 1,053 students.

In 1991-92, there were, as self-reported by students, 2,052 minority students (1,643 undergraduate and 409 graduate) at the Institute, compared with 1,978 (1,582 undergraduate and 396 graduate) in 1990-91. Minority students included 347 African Americans (non-Hispanic), 34 Native Americans, 423 Hispanic Americans, and 1,248 Asian Americans. The first-year class entering in September 1991 included 457 minority students, representing 43 percent of the class.

Degrees Awarded

Degrees awarded by the Institute in 1991-92 included 1,039 bachelor's degrees, 1,137 master's degrees, 31 engineer's degrees, and 514 doctoral degrees -- a total of 2,721 (compared with 2,771 in 1990-91).

Tabular Presentation

Most of the above 1991-92 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**: planning for the transition next fall to the new P/D/F grading system for all subjects formerly graded pass/fail; assisting the work of various Faculty Committees (e.g., in reviews of several proposals for changes in undergraduate curricula that stretch the boundaries defined by Faculty Regulations, in shaping credit and grading policies in music performance subjects, in defining limited experiments for allowing take home exams to substitute for Final Exams in HASS-D subjects, and in developing draft guidelines for enrollment management in oversubscribed subjects); supporting the work of the Institute Calendar Committee (statistical information, survey of calendars at peer institutions, draft statements of goals/issues and calendar prototypes); developing means for a pilot group of departments to electronically pass proposals for new or modified subjects for review by COC; implementing various procedures to address the Registration Day conflict with Rosh Hashanah;

Fulfilling requests for information, data files, and statistics, including studies of classroom utilization, minority student performance, the new HASS-D Requirement, and how students use their time, and support for the Academic Programs Subgroup of the Academic Council; increasing the level of analysis done in responding to requests for information; expanding our involvement in the conduct of various educational studies as a partner in defining the research problems, objectives, and methodologies -- to improve effectiveness and address privacy considerations;

Planning for the phase out of the old degree requirements, including the HUM-Distribution; finalizing and implementing policies and procedures in the event of a snow closing during Final Exams; developing procedures to better inform students about their rights to withhold address/phone information as public Directory information, while in general making this information more quickly available to the MIT community; working with the UAAO in monitoring/advising freshmen who exceed the credit limit and who change their choice of Course;

Providing ongoing planning and logistical support for the doctoral Hooding Ceremony; implementing steps to better balance the undergraduate and graduate diploma distribution lines at Commencement; developing ways to assist seniors with deficiencies the day before degree decisions are made; developing new policy for conversion of MIT credit units to semester hours on the MIT transcript; implementing a much streamlined process for registering doctoral students working on thesis only; increasing substantially academic departmental access to the student database via terminals; continuing to revise the Registration Instructions to clarify policies, procedures, and degree requirements; refining distribution policy and fee structure for mailing labels;

Assisting with renovation planning for Room 1-390; undertaking normal efforts to maintain classrooms; collaborating with Physical Plant, Planning Office, and Senior Vice President to develop short- and long-range priorities and plans to adequately maintain and renovate MIT's classrooms; and establishing a classroom inventory spreadsheet for classroom maintenance and budget planning purposes.

•**Continue the major effort to develop a new Student Information System (SIS)**: Accomplishments during the past year in the development process include: maintaining management structures for project oversight and input by the various user communities; negotiating final contracts for substantial technical programming support and for necessary peripheral software; completing a series of training sessions on SCT's Banner Systems for a core group of SIS users; making substantial progress on development of the functional process model for the SIS, based on hundreds of meetings, to define in complete detail the specifications of the new system from the users' perspective—leading to 15 major documents (2,000 pages) defining various aspects of the new SIS; holding weekly users' meetings to review each component of the system specifications; beginning the system construction phase of the project; completing (in conjunction with Information Systems) and placing in production a client-server application to provide access on Athena to a student's academic record and other information; developing a wide range of information for the "Ask the Registrar" component of the Student Access prototype; preparing a detailed policy/procedures document and holding a series of meetings with faculty/staff departmental administrators and Faculty Committees (CAP, CGSP, and COC) to address particular policy questions; defining modifications of registration procedures and Forms for use under the new SIS; implementing Banner's "Requirements Tracking Module" for the Financial Aid Office to track financial aid application material and generate letters if material is missing; making contractual arrangements to convert the GASP scheduling system to the VAX environment; and identifying and implementing a PC-based software package for final exam scheduling.

•**Make improvements to the current Student Information System and Registrar's Office PC network**: rewriting major portions of the PC-based Commencement processing programs, to make them more technically consistent and accessible; making provision to keep backup copies of the SIS Archives on the VAX (to address current tape-drive vulnerabilities); making a variety of programming updates to the SIS; strengthening communications capability on the local area PC network to the IBM mainframe and Digital VAX; making enhancements in the Catalogue database system, including the capability to accept subject proposals electronically from departments; and replacing Office hardware to get set for the new SIS.

•**Strengthen effectiveness in administrative procedures and office operations**: resubmitting a proposal to CRSP to provide central space in the main building complex for the Registrar's Office, to address professional isolation and increase our use as an institutional resource; working with the Communications Office to improve the style/content of the MIT Catalogue; implementing the capability to edit on-line the Catalogue curriculum chapter and degree charts; in collaboration with the Public Relations Services Office, making major improvements in the graphic design of the Commencement Book; developing and implementing a plan to ensure the existence of a microfilm copy of all MIT permanent academic records from 1865-1980 (including copy for off-site storage and purchase of a microfilm reader);

Implementing a full annual operations calendar for the Registrar's Office; continuing to strengthen the services of the satellite Registrar's Office in the main building; implementing procedures for electronically loading freshman AP credit into the database; planning and undertaking a series of discussions within the Office on sexual harassment issues; refining techniques to pass data electronically between the Registrar's Office and various other administrative offices (leading to significant improvements in efficiency, e.g., in producing the HASS Guide); assessing via a questionnaire students' needs to get a new schedule on Reg Day; initiating efforts to monitor mailings done with Registrar's Office address labels; and developing new procedures with the ISO for clearing International students for registration.

Important Issues on the Agenda

a) Complete development of the new Student Information System. b) Strengthen the academic research capabilities and involvements by the Registrar's Office. c) Continue the collaborative effort to develop an extensive renovation and maintenance program to provide first-rate classroom/lecture facilities at MIT.

Staff Notes

Stephen Turner joined the Office as analyst programmer III, and Andrea Bernard as technical assistant, to help with the development of the new SIS. Several well-earned promotions were made to acknowledge significant service to the Office: Phoebe Minias to assistant to the registrar (manager, catalogue and publications), Lisa Rung to administrative assistant, and JoAnne Stevenson, Elena Martsinkovsky, Lauri Hugentobler, and Christiana Gerstner to senior analyst programmer. Associate registrar Pat Flynn retired after two decades of valuable service to the Institute in the area of scheduling and classroom facilities.

DAVID S. WILEY, REGISTRAR

STUDENT FINANCIAL AID OFFICE

Statistics for the Year

During the academic year 1991-92, the financial aid program reflected the increased need of undergraduate students. A total of 2,543 students who demonstrated need for assistance (56% of the enrollment) received $28,327,000 in grant aid and $10,278,000 in student loans from all sources. The total,$38,605,000 represents a 10% increase in aid compared to last year.

Grant assistance to undergraduates was provided by $8,475,000 in income from the scholarship endowment, by $859,000 in outside gifts, by federal grants (including ROTC scholarships) totaling $3,151,000, and by $2,072,000 in direct grants from non-federal outside sources to needy students. In addition, $13,769,000 in scholarships from MIT's unrestricted funds was provided to undergraduates, inclusive of the special program of scholarship aid to needy minority group students which represented $275,000, and the MIT Opportunity Awards which accounted for $928,000. An additional 452 students received grants irrespective of need from outside agencies totaling $2,088,000. The undergraduate scholarship endowment was increased by the addition of $6,582,000 in new funds (more than last year's increase), raising the principal of the endowment by 10% to $75,090,000.

Loans totaling $9,619,000 were made to undergraduates, a 6% increase from last year. Of this amount $1,291,000 came from the Technology Loan Fund, $2,856,000 came from the Perkins Loan Program, and $5,472,000 came from state-administrated Stafford Guaranteed Loan Programs and other outside sources.

Graduate students obtained $2,570,000 from the Technology Loan Fund. In addition, $841,000 was loaned by MIT under the Stafford Guaranteed Student Loan Program. The total, $3,411,000 represents a 9% increase over last year's level. Graduate students obtained $3,853,000 from outside sources under the Stafford Guaranteed Student Loan Program, 10% more than last year, and $121,000 from federal Supplemental Student Loans. Graduate students also received $1,536,000 in Perkins Loan funds.

The total amount of loans made to undergraduate and graduate students was $18,540,000, a 9.2% increase over last year.

For the first time in many years, the number of needy undergraduate students receiving aid decreased slightly. The average need, however increased by 8.3% reflecting, in part, the higher proportion of students from low income families. This year the percentage of freshmen coming from the lowest national income quartile was 23%, the largest proportion ever. In addition, the financial aid program funded the higher need of families as the recession deepened and unemployment increased.

The total need for financial aid for undergraduates was $41,639,000. The average need for aid rose by 8.3% to $16,765. In the aggregate, the financial aid program required $19,427,000 from needy students' family resources, and provided $41,639,000 in aid dollars. As in years past, the aid program accounted for two-thirds of needy students' total costs.

Scholarships and Grants

The recession has had a significant effect on the demand for and use of MIT grant funds. In addition to the increase in average need that was seen this year, the available grants from current funds, which are sensitive to year-end contributions from donors, decreased by a third. Similarly, outside grants to students from private donors decreased by 11%. An increase in the federal grants awarded by the federal government through the Pell Grant program was not sufficient to cover the losses in the private sources. Income from endowment was also 3% below expectation. Thus, the resources designated for scholarship support again fell far short of the total demand for scholarship funds. As a result, $13,769,000 of unrestricted funds were used to meet the shortfall. The MIT Opportunity Grants Program accounted for $928,000 of this funding.

The following table displays the sources of grants and scholarships received by needy students in the last three years:

Scholarships and Grants*
(awarded to undergraduates with need)

Source	1989-90	1990-91	1991-92
Pell Grants	$ 933,000	$ 901,000	$ 1,050,000
SEO Grants	1,352,000	1,366,000	1,411,000
ROTC Scholarships	670,000	638,000	690,000
Scholarship Endowment	7,616,000	8,032,000	8,475,000
Current Gifts	1,096,000	1,277,000	859,000
Direct Grants	2,058,000	2,096,000	2,072,000
Unrestricted Funds¶	9,416,000	11,748,000‡	13,769,000
Total Grants Awarded	**$23,141,000**	**$26,058,000**	**28,326,000**

*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.

‡Includes $130,000 charged in 1991-92.

Loans

During the year both undergraduates and graduates borrowed more than last. Undergraduates, needy and non-needy, increased borrowing in the aggregate by 5.9%. Most of the funding for this increase came from the federal Stafford Student Loan program with modest dollar increases coming from both the MIT Technology Loan fund and the federal Perkins Loan Fund.

Graduate students increased their borrowing in the aggregate by 13%. Increased need for loans was met primarily from sources other than the federal Stafford Student Loan Program. Funding from MIT's Technology Loan Fund increased by 12%. The federal Perkins Loan Program was again available to graduate students and the 85% increase in these funds to graduate students ($827,000 to$1,536,000) funded much of the additional need for loans.

The following table details the use of loans by undergraduate and graduate students:

Loans
(received by needy and non-needy students)

Source	1989-90	1990-91	1991-92
A. Awarded to Undergraduates			
Technology Loan Fund	$ 1,151,000	$ 1,162,000	$ 1,291,000
Perkins/National Direct Loans	3,196,000	2,758,000	2,856,000
Stafford Student Loans	4,572,000	5,163,000	5,472,000
Sub-Total	**$8,919,000**	**$9,083,000**	**9,619,000**
B. Awarded to Graduate Students			
Technology Loan Fund	$ 2,552,000	$ 2,295,000	$ 2,570,000
Stafford Student Loans by Commercial Lenders	3,239,000	3,513,000	3,853,000
Stafford Student Loans by MIT	571,000	1,082,000	841,000
Perkins Loan	0	827,000	1,536,000
PLUS Loans & Supplementary Loans for Students	94,000	181,000	121,000
Sub-Total	**$6,456,000**	**$7,898,000**	**8,921,000**

Work Programs

The off-campus job market showed a 9% percent increase 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 was $6.75 per hour.

The College Work-Study Program allocation decreased slightly from the 1990-91 level and was used entirely to subsidize the on-campus student employment program. As in the recent past, approximately half of the total 1991-1992 allocation was used to subsidize undergraduate work, and half to subsidize graduate student teaching assistantships.

Other Activities of Interest

• Beginning on June 26th in the Federal District Court of Philadelphia, MIT faced the U.S. Justice Department's charge that the practice of financial aid as conducted over the past twenty-five years has been in violation of the Sherman Anti-Trust Act. The trial took two weeks with a decision expected early in the fall of 1992. The trial was widely covered by the national media which provided almost unanimous support of MIT in its practices which have been designed to assure that financial aid funds are used exclusively for needy students.

• Development of the new student information system continued. The Student Financial Aid Office was the first office to use the new Banner system in a production mode, implementing an application document

tracking system which uses the enhanced capabilities of the system. The SFAO was able to provide valuable experience in the use of the system that will facilitate the conversion of the entire system in a year.

Staff Notes

Stanley Hudson will be promoted from Associate Director and Executive Officer to Director, as of July 1, upon my retirement. At the beginning of the year, Dan Langdale re-joined the staff of the SFAO as Associate Director. Patricia Carroll was promoted from Assistant to Associate Director in recognition of her expanded responsibilities in donor relations.

LEONARD V. GALLAGHER, DIRECTOR

TABLE I NUMBER OF STUDENTS BY COURSE AND YEAR 1991-92*

COURSE NAME	1	2	3	4	G	Non-Res.[1]	Grand Total	Course Number
SCHOOL OF ARCHITECTURE AND PLANNING								
Architecture, IV		30	28	30	269 (5)	15	372 (5)	IV
Architecture, IV-B		1	2	3	-	-	6	IV-B
Urban Studies and Planning, XI		2	2	3	168 (20)	15	190 (20)	XI
Total		33	32	36	437 (25)	30	568 (25)	Total
SCHOOL OF ENGINEERING								
Aeronautics and Astronautics, XVI		64	58	52	212 (6)	-	386 (6)	XVI
Aeronautics and Astronautics, XVI-C (Internship)		-	2	14	-	-	16	XVI-C
Chemical Engineering, X		88	72	53	202 (1)	-	415 (1)	X
Chemical Engineering, X-C		2	2	3	-	-	7	X-C
Civil Engineering, I		11	15	23	290 (11)	5	344 (11)	I
Civil Engineering, I-A		2	3	3	-	-	8	I-A
Civil Engineering, I-E		18	18	20	-	-	56	I-E
Civil Engineering, I-W (Woods Hole)		-	-	-	9	-	9	I-W
Electrical Engineering and Computer Science, VI		-	-	-	610 (32)	1	611 (32)	VI
Program 1-Electrical Science and Engineering		159	167	117 (2)	-	-	443 (2)	VI-1
Program 3-Computer Science and Engineering		142	91	81 (1)	-	-	314 (1)	VI-3
Electrical Engineering and Computer Science, VI-A (Internship)		-	-	-	91 (1)	-	91 (1)	VI-A
Program 1-Electrical Science and Engineering		-	47	61	-	-	108	VI-1A
Program 3-Computer Science and Engineering		-	23	29	-	-	52	VI-3A
Electrical Engineering and Computer Science, VI-W (Woods Hole)		-	-	-	5	-	5	VI-W
Materials Science and Engineering, III		34	7	14	188 (5)	2	245 (5)	III
Materials Science and Engineering, III-A		1	1	1	-	-	3	III-A
Materials Science and Engineering, III-B (Internship)		4	41	29	-	-	74	III-B
Mechanical Engineering, II		132	100	123	416 (15)	-	771 (15)	II
Mechanical Engineering, II-A		13	17	18	-	-	48	II-A
Mechanical Engineering, II-B (Internship)		-	18	17	-	-	35	II-B
Mechanical Engineering, II-W (Woods Hole)		-	-	-	3	-	3	II-W
Nuclear Engineering, XXII		6	2	3	126 (2)	2	139 (2)	XXII
Nuclear Engineering, XXII-A (Internship)		-	-	2	-	-	2	XXII-A
Ocean Engineering, XIII		2	3	3	90 (3)	1	99 (3)	XIII
Ocean Engineering, XIII-W (Woods Hole)		-	-	-	23	-	23	XIII-W
Naval Construction and Engineering, XIII-A		-	-	-	36	-	36	XIII-A
Ocean Systems Management, XIII-B		-	-	-	6	-	6	XIII-B
Center for Advanced Engineering Study, EN		-	-	-	58 (58)	-	58 (58)	EN
Total		678	687	666 (3)	2,365 (134)	11	4,407 (137)	Total
SCHOOL OF HUMANITIES AND SOCIAL SCIENCE								
Economics, XIV		17	30	33	137 (3)	7	224 (3)	XIV
Anthropology/Archaeology, XXI-Y		1	1	1	-	-	3	XXI-Y
History, XXI-H		-	4	2	-	-	6	XXI-H
Literature, XXI-L		1	1	5	-	-	7	XXI-L
Music and Theater Arts, XXI-M		1	3	1	-	-	5	XXI-M
Writing, XXI-W		3	4	3	-	-	10	XXI-W
Humanities, XXI-D, XXI-P		-	1	1	-	-	2	XXI-D, XXI-P

Humanities and Engineering, XXI-E		-	1	8	-	-	9		XXI-E
Humanities and Science, XXI-S		-	2	5	-	-	7		XXI-S
Linguistics and Philosophy, XXIV		-	2	6	57 (1)	3	68	(1)	XXIV
Political Science, XVII		4	15	18	126 (6)	43	206	(6)	XVII
Program in Science, Technology, and Society, XXI-T, STS		1	-	-	17	-	18		XXI-T, STS
Total		28	64	83	337 (10)	53	565	(10)	Total
SLOAN SCHOOL OF MANAGEMENT									
Management, XV		28	35	50	518 (11)	1	632	(11)	XV
Management Fellows, XV-A		-	-	-	61 (7)	-	61	(7)	XV-A
Management-Operations Research, XV-B		-	-	-	22	-	22		XV-B
Management-Ph.D., XV-P		-	-	-	83	-	83		XV-P
Total		28	35	50	684 (18)	1	798	(18)	Total
SCHOOL OF SCIENCE									
Program in Applied Biological Sciences, XX		-	-	-	14	1	15		XX
Biology, VII		68	73	63	184 (3)	4	392	(3)	VII
Biology, VII-A		4	1	10	-	-	15		VII-A
Biology, VII-W (Woods Hole)		-	-	-	23	-	23		VII-W
Chemistry, V		42	33	30	249 (2)	7	361	(2)	V
Earth, Atmospheric, and Planetary Sciences, XII		3	10	12	100 (2)	-	125	(2)	XII
Earth, Atmospheric, and Planetary Sciences, XII-W (Woods Hole)		-	-	-	68	-	68		XII-W
Mathematics, XVIII		35	37	49 (1)	116 (2)	5	242	(3)	XVIII
Mathematics with Computer Science, XVIII-C		22	14	11	-	-	47		XVIII-C
Physics, VIII		56	60	58 (1)	301 (1)	1	476	(2)	VIII
Physics, VIII-A		21	10	8	-	-	39		VIII-A
Total		251	238	241 (2)	1,055 (10)	18	1,803	(12)	Total
WHITAKER COLLEGE of Health Sciences and Technology									
Brain and Cognitive Sciences, IX		8	7	15	57 (2)	-	87	(2)	IX
Division of Toxicology, TOX		-	-	-	27	-	27		TOX
Total		8	7	15	84 (2)	-	114	(2)	Total
Harvard-MIT Division of Health Sciences and Technology, HST		-	-	-	141 (50)	-	141	(50)	HST
Undesignated		75	17 (17)	-	-	-	92	(17)	Undesignated
First Year	1,053	-	-	-	-	-	1,053		First Year
Grand Total	1,053	1,101	1,080 (17)	1,091 (5)	5,103 (249)	113	9,541	(271)	Grand Total
Not included in above totals:									
Foreign Study: 1 student in the second year, 4 students in the third year, 2 students in the fourth year.									
Non-Institute Brandeis		-	-	-	1	-	1		NIR
Non-Institute Harvard	13	21	11	40	246	-	331		NIH
Non-Institute Tufts	11	10	6	7	-	-	34		NIT
Non-Institute Wellesley	-	28	36	40	-	-	104		NIW

*All figures include special students (special students also shown separately in parentheses)
[I]Non-resident graduate students

TABLE II ACADEMIC STAFF COUNT 1991-92

	Professors *	Administration also Professors *	Institute Professors Emeriti-Part Time *	Adjunct Professors *	Associate Professors *	Assistant Professors *	Sr. Lecturers and Professors Emeriti *	Sr. Lecturers	Lecturers	Sr. Research Scientists	Instructors	Technical Instructors	Sr. Research Associates	Postdoctoral Associates	Research Assistants	Teaching Assistants	Instructor Grad	Total	Visiting Professors	Other[1]
INSTITUTE PROFESSORS	11	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18	-	-
SCHOOL OF ARCHITECTURE AND PLANNING																				
Architecture	11	1	-	1	6	13	-	1	10	-	2	2	-	-	6	76	-	129	11	11
Urban Studies and Planning	13	2	-	3	4	4	3	3	5	-	-	-	-	-	20	12	1	70	3	37
Media Arts and Sciences Sect.	3	1	-	1	5	5	-	-	-	-	-	-	-	-	75	-	-	90	-	6
Total	27	4	-	5	15	22	3	4	15	-	2	2	-	-	101	88	1	289	14	54
SCHOOL OF ENGINEERING	1	-	-	-	3	-	1	-	1	-	-	-	-	-	-	-	-	6	-	-
Aeronautics and Astronautics	17	2	-	3	9	7	4	2	12	-	-	3	-	2	130	10	-	201	3	13
Chemical Engineering	19	2	-	1	3	7	2	1	1	-	1	1	-	16	106	30	-	190	-	31
Civil Engineering	23	4	-	-	5	7	1	3	5	-	1	-	1	2	147	18	3	220	1	18
Electrical Engineering and Computer Science	58	15	-	3	23	12	10	1	9	1	-	4	-	4	371	107	5	623	2	20
Materials Science and Engineering	13	6	-	1	9	6	5	2	-	-	-	2	1	16	109	11	-	181	2	22
Mechanical Engineering	25	4	-	1	18	8	10	7	28	1	-	6	1	6	263	29	-	407	3	23
Nuclear Engineering	15	2	-	-	3	2	-	-	1	2	-	-	-	1	80	16	-	122	1	10
Ocean Engineering	13	1	-	-	7	1	1	4	7	-	-	-	-	4	56	8	-	102	3	11
Program in Technology and Policy	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	-	3	-	-
Total	184	36	-	9	80	50	34	20	64	4	2	16	3	51	1,264	230	8	2,055	15	148
SCHOOL OF HUMANITIES AND SOCIAL SCIENCE	-	-	-	-	-	-	-	-	2	-	-	1	-	-	-	-	-	3	-	-
Economics	18	1	-	-	2	7	-	-	-	-	3	-	-	-	10	29	-	70	4	11
Anthropology/Archaeology	3	1	-	-	1	1	-	-	4	-	-	-	-	-	-	-	-	10	-	-
Foreign Languages and Literatures	4	-	-	-	4	-	-	2	18	1	-	-	-	-	-	-	-	29	7	-
History	4	1	-	-	4	6	-	-	-	-	-	-	-	-	-	-	-	15	2	3
Literature	9	2	-	-	3	3	-	-	5	-	1	-	-	-	-	-	-	23	1	-
Music and Theater Arts	5	2	-	-	2	2	-	3	12	-	-	4	-	-	-	-	-	30	-	7
Writing Program	3	1	-	1	2	1	-	2	17	-	-	9	-	-	-	-	-	36	-	6
Linguistics and Philosophy	13	2	-	-	4	2	-	-	-	-	1	-	-	-	10	8	-	40	-	27
Political Science	14	1	-	1	5	2	-	-	2	-	-	-	-	-	27	19	-	71	2	5
Program in Science, Technology, and Society	5	1	-	-	-	2	2	-	-	-	-	1	1	-	7	3	-	22	3	18
Total	78	12	-	2	27	26	2	7	60	1	5	15	1	-	54	59	-	349	19	77
SLOAN SCHOOL OF MANAGEMENT																				
Management	35	3	-	2	23	28	1	8	2	1	-	-	-	-	104	71	-	278	13	24
SCHOOL OF SCIENCE	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Biology	34	2	-	-	9	8	1	1	-	2	3	1	-	54	47	-	-	162	5	97
Chemistry	20	2	-	-	4	4	2	-	-	1	-	1	-	45	129	47	-	255	-	66
Earth, Atmospheric, and Planetary Sciences	25	1	-	-	11	1	1	1	-	2	-	-	-	11	90	15	-	158	5	46
Mathematics	37	1	-	-	3	9	-	-	3	-	22	-	-	1	21	59	1	157	4	24
Physics	49	6	-	-	10	16	6	1	-	11	-	7	-	10	234	35	1	386	1	18
Total	166	12	-	-	37	38	10	3	3	16	25	9	-	121	521	156	2	1,119	15	251
WHITAKER COLLEGE OF HEALTH SCIENCES AND TECHNOLOGY	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Brain and Cognitive Sciences	16	2	-	-	5	4	-	-	5	-	-	2	-	2	6	4	-	46	3	72
Toxicology	2	2	-	-	-	2	-	-	1	-	-	-	-	6	13	2	-	28	-	14
Total	18	4	-	-	5	6	-	-	6	-	-	2	-	8	19	6	-	74	3	87

Administration	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Aga Khan Program in Islamic Architecture	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
Air Force Aerospace Studies	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	5	1	-
Artificial Intelligence Laboratory	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	12
Athletic Department	-	1	-	-	11	4	-	-	-	-	14	-	-	-	-	-	-	30	-	15
Biotechnology Process Engineering Ctr.	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	2	-	10
Center for Advanced Engineering Studies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Center for Advanced Visual Studies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7
Center for Cancer Research	-	-	-	-	-	-	-	-	-	-	-	-	-	21	-	-	-	21	-	72
Center for Cognitive Science	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13
Center for Environmental Health Sciences	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	5	-	5
Center for International Studies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24
Center for Technology Policy and Industrial Development	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-	10
Center for Materials Research in Archaeology and Ethnology	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-	2	-	-
Center for Materials Science and Engineering	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	4	-	7
Center for Space Research	-	-	-	-	-	-	-	-	-	1	-	-	-	2	-	-	-	3	-	6
Center for Transportation Studies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Clinical Research Center	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	3	-	31
Concourse	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-
Division of Comparative Medicine	-	1	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	5	-	15
Energy Laboratory	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	4	-	19
Experimental Study Group	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	3	-	-
Francis Bitter National Magnet Laboratory	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	3	-	43
Harvard-MIT Division of Health Sciences and Technology	2	-	-	-	2	-	1	1	4	1	5	-	1	2	63	2	-	84	1	70
Haystack Observatory	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	1
Laboratory for Computer Science	-	-	-	-	-	-	-	-	-	2	-	-	-	1	-	-	-	3	-	18
Laboratory for Electromagnetic and Electronic Systems	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9
Laboratory for Information and Decision Systems	-	-	-	-	-	-	-	-	1	-	-	-	-	2	-	-	-	3	-	7
Laboratory for Manufacturing and Productivity	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	2	-	11
Laboratory for Nuclear Science	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	40
Leaders for Manufacturing	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Materials Processing Center	-	-	-	-	-	-	-	-	-	1	-	-	-	5	-	-	-	6	-	12
Media Laboratory	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	2	-	17
Medical Department	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	169
Military Science	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	4	1	-
Naval Science	-	-	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-	6	3	-
Nuclear Reactor Laboratory	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16
Office of the Provost	1	-	-	-	-	-	-	1	2	-	-	2	-	-	-	-	-	6	-	3
Operations Research Center	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Plasma Fusion Center	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	3	-	26
Research Laboratory of Electronics	-	-	-	-	-	-	-	-	-	3	-	-	-	8	-	-	-	11	-	75
Sea Grant Program	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
Spectroscopy Laboratory	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	15
Student Activities	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	4	-	-
Technology Development Program	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
Total	3	3	-	-	13	4	1	2	11	14	19	22	2	70	65	2	-	231	6	794
Grand Total	522[2]	74[2]	7[2]	18[2]	200[2]	174[2]	51[2]	44[2]	161[2]	36	53[2]	66[2]	6	250	2,128	612[2]	11[2]	4,413	85[3,4]	1,435[3]
Faculty Ex Officils *																		25		
																		4,438		

*Total Faculty 1,071

[1]Includes 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.

[2]Total Teaching Staff 1,993

[3]Not included in preceding total

[4]Visiting Professors include 47 Professors, 19 Associate Professors, 19 Assistant Professors.

TABLE III NUMBER OF DEGREES AWARDED IN SEPTEMBER 1991, FEBRUARY 1992, AND JUNE 1992

	S.B.			S.M.			M.ARCH. M.C.P.			ENGINEER			Ph.D.			Sc.D.			TOTAL		
	SEPT	FEB	JUNE	SEPT	FEB	JUNE	SEPT	FEB	JUNE	SEPT	FEB	JUNE	SEPT	FEB	JUNE	SEPT	FEB	JUNE	SEPT	FEB	JUNE
SCHOOL OF ARCHITECTURE																					
Architecture	-	-	-	-	-	-	-	14	19	-	-	-	4	4	2	-	-	-	4	18	21
Undesignated	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Architecture Studies	-	-	-	-	5	19	-	-	-	-	-	-	-	-	-	-	-	-	-	5	19
Art and Design	2	4	27	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	4	27
Building Technology	-	-	-	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1
Planning	-	-	1	-	-	-	2	5	37	-	-	-	-	-	-	-	-	-	2	5	38
Real Estate Development	-	-	-	27	1	4	-	-	-	-	-	-	-	-	-	-	-	-	27	1	4
Urban Studies and Planning	-	-	-	-	-	-	-	-	-	-	-	-	4	1	3	-	-	-	4	1	3
Visual Studies	-	-	-	4	-	5	-	-	-	-	-	-	-	-	-	-	-	-	4	-	5
Total	2	4	30	32	7	29	2	19	56	-	-	-	8	5	5	-	-	-	44	35	120
SCHOOL OF ENGINEERING																					
Aeronautics and Astronautics	2	8	56	20	16	25	-	-	-	-	-	-	2	5	17	-	-	2	24	29	100
Chemical Engineering	-	1	47	-	1	4	-	-	-	-	-	-	6	13	9	-	2	2	6	17	62
Undesignated	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
Chemical Engineering Practice	-	-	-	6	8	9	-	-	-	-	-	-	-	-	-	-	-	-	6	8	9
Civil Engineering	1	5	12	10	23	20	-	-	-	2	-	1	3	9	9	3	4	-	19	41	42
Undesignated	-	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2
Computer Science and Engineering	6	7	78	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	7	78
Electrical Engineering	7	12	135	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	12	135
Electrical Engineering and Computer Science	-	-	-	31	24	97	-	-	-	2	2	9	13	24	23	-	1	-	46	51	129
Electronic Materials	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Environmental Engineering Science	-	-	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18
Materials Engineering	-	-	-	2	4	11	-	-	-	-	-	-	-	-	-	-	-	-	2	4	11
Materials Science	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Materials Science and Engineering	-	7	35	-	-	-	-	-	-	-	-	-	7	6	11	-	3	1	7	16	47
Undesignated	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Mechanical Engineering	1	18	105	16	31	69	-	-	-	-	-	-	7	5	15	1	2	1	25	56	190
Undesignated	-	2	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	12
Metallurgy	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Naval Architecture and Marine Engineering	-	-	3	-	1	8	-	-	-	-	-	-	-	-	-	-	-	-	-	1	11
Naval Engineering	-	-	-	-	-	-	-	-	-	-	-	7	-	-	-	-	-	-	-	-	7
Nuclear Engineering	-	1	6	6	10	8	-	-	-	1	2	-	6	7	7	-	-	-	13	20	21
Ocean Engineering	1	-	1	5	3	6	-	-	-	-	2	1	-	2	3	1	1	1	7	8	12
Ocean Systems Management	-	-	-	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1
Polymers	-	-	-	-	1	6	-	-	-	-	-	-	-	-	-	-	-	-	-	1	6
Total	18	63	515	98	125	265	-	-	-	5	6	18	44	71	94	5	13	7	170	278	899
SCHOOL OF HUMANITIES AND SOCIAL SCIENCE																					
Anthropology/Archaeology	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Economics	2	3	33	1	-	1	-	-	-	-	-	-	4	4	15	-	-	-	7	7	49
Foreign Languages and Literatures	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
History	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Humanities	2	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2

Humanities and Engineering	-	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7
Humanities and Science	2	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	5
Linguistics	-	-	-	1	-	-	-	-	-	-	-	-	7	1	2	-	8	1	2
Literature	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
Music	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Philosophy	-	-	6	-	1	-	-	-	-	-	-	-	-	1	2	-	-	2	8
Political Science	1	2	16	2	8	4	-	-	-	-	-	-	1	4	8	-	4	14	28
Writing	-	1	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	3
Total	7	8	81	4	9	5	-	-	-	-	-	-	12	10	27	-	23	27	113
SLOAN SCHOOL OF MANAGEMENT																			
Management	-	-	-	3	28	279	-	-	-	-	-	-	6	12	11	-	9	40	290
Management Science	4	2	42	-	-	-	-	-	-	-	-	-	-	-	-	-	4	2	42
Total	4	2	42	3	28	279	-	-	-	-	-	-	6	12	11	-	13	42	332
SCHOOL OF SCIENCE																			
Applied Biological Sciences	-	-	-	1	-	-	-	-	-	-	-	-	3	3	3	-	4	3	4
Biology	-	11	52	-	-	1	-	-	-	-	-	-	4	2	16	-	4	13	69
Undesignated	-	3	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	18
Chemistry	-	-	30	-	2	2	-	-	-	-	-	-	11	14	19	-	11	16	51
Earth and Planetary Sciences	-	-	-	2	-	2	-	-	-	-	-	-	-	-	-	-	2	-	2
Earth, Atmospheric, and Planetary Sciences	-	-	7	-	-	-	-	-	-	-	-	-	5	3	4	1	6	3	11
Mathematics	2	4	51	-	-	2	-	-	-	-	-	-	9	2	14	-	11	6	67
Mathematics with Computer Science	2	2	7	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	7
Meteorology	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	1	1
Physics	4	3	52	5	2	4	-	-	-	-	-	-	11	11	15	-	20	16	71
Total	8	23	217	8	5	12	-	-	-	-	-	-	43	35	71	1	60	63	301
WHITAKER COLLEGE of Health Sciences and Technology																			
Cognitive Science	2	-	13	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	13
Brain and Cognitive Sciences	-	-	-	-	-	-	-	-	-	-	-	-	5	2	2	-	5	2	2
Toxicology	-	-	-	1	1	-	-	-	-	-	-	-	-	2	1	-	1	3	1
Total	2	-	13	1	1	-	-	-	-	-	-	-	5	4	3	-	8	5	16
Harvard-MIT Division of Health Sciences and Technology																			
Applied Biology and Medicine	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-
Health Sciences and Technology	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1
Medical Engineering	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	2
Medical Physics	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	2	-
Management of Technology	-	-	-	-	-	38	-	-	-	-	-	-	-	-	-	-	-	-	38
Operations Research	-	-	-	4	3	6	-	-	-	-	-	-	-	-	-	-	4	3	6
Technology and Policy	-	-	-	4	4	20	-	-	-	-	-	-	-	-	-	-	4	4	20
Transportation	-	-	-	2	6	7	-	-	-	-	-	-	-	-	-	-	2	6	7
Without Course Specification	-	-	-	6	8	29	-	-	-	-	-	-	-	-	-	-	6	8	29
Awarded Jointly with Woods Hole Oceanographic Institution																			
Biology	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-
Civil Engineering	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-	1	1
Earth, Atmospheric, and Planetary Sciences	-	-	-	4	-	-	-	-	-	-	-	-	3	1	6	-	7	1	6
Electrical Engineering and Computer Science	-	-	-	1	1	-	-	-	-	-	-	1	-	1	-	-	1	2	1
Ocean Engineering	-	-	-	2	1	1	-	-	-	1	-	-	1	-	1	1	5	1	2
Grand Total	41	100	898	169	198	693	2	19	56	6	6	19	123	143	220	7	348	479	1,894

TABLE IV NUMBER OF WOMEN STUDENTS BY COURSE AND YEAR 1991-92[1]

COURSE NAME	1	2	3	4	G	Non-Res.[2]	Grand Total	Course Number
SCHOOL OF ARCHITECTURE AND PLANNING								
Architecture, IV		21	15	12	87 (3)	4	139 (3)	IV
Architecture, IV-B		1	-	2	-	-	3	IV-B
Urban Studies and Planning, XI		1	2	2	83 (14)	7	95 (14)	XI
Total		23	17	16	170 (17)	11	237 (17)	Total
SCHOOL OF ENGINEERING								
Aeronautics and Astronautics, XVI		19	15	12	19	-	65	XVI
Aeronautics and Astronautics, XVI-C (Internship)		-	-	4	-	-	4	XVI-C
Chemical Engineering, X		42	45	30	42	-	159	X
Chemical Engineering, X-C		1	1	2	-	-	4	X-C
Civil Engineering, I		5	3	7	53 (2)	1	69 (2)	I
Civil Engineering, I-A		1	1	-	-	-	2	I-A
Civil Engineering, I-E		8	11	16	-	-	35	I-E
Civil Engineering, I-W (Woods Hole)		-	-	-	3	-	3	I-W
Electrical Engineering and Computer Science, VI		-	-	-	110 (4)	1	111 (4)	VI
Program 1-Electrical Science and Engineering		26	39	28	-	-	93	VI-1
Program 3-Computer Science and Engineering		22	12	10	-	-	44	VI-3
Electrical Engineering and Computer Science, VI-A (Internship)		-	-	-	20	-	20	VI-A
Program 1-Electrical Science and Engineering		-	8	13	-	-	21	VI-1A
Program 3-Computer Science and Engineering		-	3	3	-	-	6	VI-3A
Materials Science and Engineering, III		13	3	7	54 (2)	-	77 (2)	III
Materials Science and Engineering, III-B (Internship)		3	23	17	-	-	43	III-B
Mechanical Engineering, II		39	22	28	50 (2)	-	139 (2)	II
Mechanical Engineering, II-A		5	6	2	-	-	13	II-A
Mechanical Engineering, II-B (Internship)		-	1	4	-	-	5	II-B
Nuclear Engineering, XXII		4	1	1	12	-	18	XXII
Nuclear Engineering, XXII-A (Internship)		-	-	2	-	-	2	XXII-A
Ocean Engineering, XIII		-	2	2	11	-	15	XIII
Ocean Engineering, XIII-W (Woods Hole)		-	-	-	3	-	3	XIII-W
Naval Construction and Engineering, XIII-A		-	-	-	5	-	5	XIII-A
Ocean Systems Management, XIII-B		-	-	-	1	-	1	XIII-B
Center for Advanced Engineering Study, EN		-	-	-	7 (7)	-	7 (7)	EN
Total		188	196	188	390 (17)	2	964 (17)	Total
SCHOOL OF HUMANITIES AND SOCIAL SCIENCE								
Economics, XIV		4	11	17	33	1	66	XIV
Anthropology/Archaeology, XXI-Y		-	-	1	-	-	1	XXI-Y
History, XXI-H		-	1	1	-	-	2	XXI-H
Literature, XXI-L		1	-	1	-	-	2	XXI-L
Music, XXI-M		-	1	-	-	-	1	XXI-M
Writing, XXI-W		2	2	1	-	-	5	XXI-W
Humanities, XXI-D, XXI-P		-	1	1	-	-	2	XXI-D, XXI-P
Humanities and Engineering, XXI-E		-	1	3	-	-	4	XXI-E
Humanities and Science, XXI-S		-	2	3	-	-	5	XXI-S
Linguistics and Philosophy, XXIV		-	1	3	15	-	19	XXIV

Political Science, XVII		1	5	6	37	(2)	21	70 (2)	XVII
Program in Science, Technology, and Society, XXI-T, STS		1	-	-	7		-	8	XXI-T, STS
Total		9	25	37	92	(2)	22	185 (2)	Total
SLOAN SCHOOL OF MANAGEMENT									
Management, XV		14	13	16	111	(4)	-	154 (4)	XV
Management Fellows, XV-A		-	-	-	5		-	5	XV-A
Management-Operations Research, XV-B		-	-	-	7		-	7	XV-B
Management-Ph.D., XV-P		-	-	-	14		-	14	XV-P
Total		14	13	16	137	(4)	-	180 (4)	Total
SCHOOL OF SCIENCE									
Program in Applied Biological Sciences, XX		-	-	-	6		-	6	XX
Biology, VII		36	42	34	72	(2)	1	185 (2)	VII
Biology, VII-A		2	1	5	-		-	8	VII-A
Biology, VII-W (Woods Hole)		-	-	-	16		-	16	VII-W
Chemistry, V		20	21	14	69		3	127	V
Earth, Atmospheric, and Planetary Sciences, XII		1	4	6	26	(2)	-	37 (2)	XII
Earth, Atmospheric, and Planetary Sciences, XII-W (Woods Hole)		-	-	-	20		-	20	XII-W
Mathematics, XVIII		12	12	15	18		-	57	XVIII
Mathematics with Computer Science, XVIII-C		9	5	2	-		-	16	XVIII-C
Physics, VIII		13	10	12	31		-	66	VIII
Physics, VIII-A		3	2	-	-		-	5	VIII-A
Total		96	97	88	258	(4)	4	543 (4)	Total
WHITAKER COLLEGE of Health Sciences and Technology									
Brain and Cognitive Sciences, IX		2	2	8	13	(2)	-	25 (2)	IX
Division of Toxicology, TOX		-	-	-	13		-	13	TOX
Total		2	2	8	26	(2)		38 (2)	Total
Harvard-MIT Division of Health Sciences and Technology, HST		-	-	-	44	(18)	-	44 (18)	HST
Undesignated		20	10	(10) -	-		-	30 (10)	Undesignated
First Year	368	-	-	-	-		-	368	First Year
Grand Total	368	352	360	(10) 353	1,117	(64)	39	2,589 (74)	Grand Total

[1]All figures include special students (special students also shown separately in parentheses); not included are: 1 student in the fourth year on Foreign Study.
[2]Non-Resident graduate students
TOTAL UNDERGRADUATE WOMEN 1991-92: 1,433

For fiscal year 1992, the total volume of sponsored research performed on campus approximated $322,266,891. This represents an increase of 2.0 percent over fiscal 1991 volume of $315,819,150 which was, in turn, an increase of 1.7 percent over fiscal 1990.

Federally funded research volume increased by less than .1 percent (compared with 1.7 percent in 1991, with Department of Health and Human Services funding up 2.0 percent, Department of Energy down 5.4 percent, the Department of Defense down 1.2 percent, the National Science Foundation down by 3.6 percent and the National Aeronautics and Space Administration up 13.0 percent.

Of the non-Federal sponsors, industrial funding increased by 10.8 percent, compared with an increase of 4.6 percent in 1991 and an increase of 10.2 percent in 1990. Support from private foundations and other non-profit sponsors increased by 4.9 percent. It should be noted that sponsorship characterized as non-Federal may, nonetheless, involve Federal funds where the industrial or non-profit sponsor has a grant or contract with the Federal government under which MIT receives a subaward.

The breakdown by sponsor is shown in the following table:

CAMPUS RESEARCH VOLUME BY SPONSOR - 1986-1992
(in thousands of dollars)

FEDERAL		1986	1987	1988	1989	1990	1991	1992
DHHS	$	45,735	47,310	49,070	52,565	57,915	59,025	60,177
DOE	$	54,511	55,062	55,629	54,045	61,098	60,625	57,355
DOD	$	43,418	45,418	46,836	47,921	51,158	49,104	48,539
NSF	$	36,772	38,091	39,177	38,962	38,093	37,953	36,574
NASA	$	12,864	12,706	12,509	15,256	18,469	22,755	25,889
Other	$	7,823	8,238	7,283	6,713	7,430	8,647	9,773
Subtotal	$	201,123	206,825	210,504	215,462	234,163	238,109	238,307
NON-FEDERAL								
Industry	$	36,290	36,601	35,315	41,937	46,223	48,360	53,578
Nonprofit	$	15,532	15,319	19,779	23,602	25,220	23,751	24,920
Other	$	3,151	4,009	3,796	4,727	5,053	5,599	5,461
Subtotal	$	54,973	55,929	58,890	70,266	76,496	77,710	83,959
TOTAL	$	256,096	262,754	269,394	285,728	310,660	315,819	322,267

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:

Future Research Funding and Cost Recovery

It is anticipated that the growth in research funding levels over the next few years will be limited as the result of general government budget constraints, including the reduction and redirection of the Defense Department budget, the broader distribution of research funding to other universities, including public institutions, the effects of congressional earmarking and geographic dispersion, and the adverse effects of the economy on industrial and foundation sponsorship.

Furthermore, in the aftermath of Congressional hearings held in the spring of 1991 on indirect cost practices at research universities, the political climate for reimbursement of expenses for indirect costs could significantly our recovery practices and level of reimbursement. These changes are evident in recent congressional attention to university reimbursement for

indirect costs and the significantly greater activity at MIT by the DCAA auditing staff, which has questioned many practices entered into jointly between MIT and the government and may unilaterally require changes. Although MIT intends to appeal a number of issues, the criteria for determining the allowability of indirect costs are likely to become increasingly narrow and to require that the benefits to the research program must be direct and clearly demonstrable.

Research Assistant Tuition

At the close of the year, OMB had not yet reached a decision on whether MIT and three other major research universities would be permitted to continue charging the tuition of graduate student research assistants to the employee benefit pool rather than to the individual research projects on which they are employed. The focal point of the debate is currently a position paper prepared for a national task force of university and government representatives considering revisions to the cost principles embodied in OMB Circular A-21.

MIT has taken the position that all universities should have the option of choosing the employee benefit method where it will result in savings to the government. The Institute believes that this is the only option which is consistent with two of the most fundamental principles of Circular A-21, i.e., that universities should be permitted to conduct their research and educational activities in a manner consonant with their own academic philosophies and institutional objectives and that A-21 should be implemented in a manner which recognizes the dual role of students engaged in research and the resulting benefits to sponsored agreements.

Conflict of Interest

Over the last year unexplained delays have prevented the issuing of a proposed PHS policy on conflicts of interest to replace the guidelines which were issued in 1990 but subsequently withdrawn by the Secretary of Health and Human Services after a largely negative response from a variety of constituencies.

At the close of the fiscal year, however, a draft of the proposed PHS policy became available and was being evaluated by the university community with the expectation that it would be published for formal comment by the end of the year. The draft policy would require that each university establish policies and procedures for avoiding certain prohibited financial interests by the principle investigator, dependents and business partners when the primary purpose of the research is to evaluate commercial marketability; establish an institutional committee to review financial disclosure statements from each investigator; maintain records of all disclosures and Committee activities; establish procedures for resolving allegations of conflict; establish a range of sanctions for those who do not comply as well as appropriate appeals procedures; and notify PHS of any unresolved conflicts.

GAO Study of University Licensing Practices

In fiscal 1991, after a pilot survey of five institutions, the GAO, conducted a mail survey of the policies of 38 top university recipients of NSF and NIH funding, including MIT, to determine how issues of fairness and conflicts of interest were addressed in the licensing of research results. This was followed up with on-site interviews with selected administrators and faculty.

The resulting report, entitled "University Research: Controlling Inappropriate Access to Federally Funded Research Results," was issued in May 1992. It concluded that growing interactions between universities and business increase the potential for conflicts of interest and for providing businesses with an unfair advantage in commercializing the results of federally funded research. It recommended as a first step that investigators and other key personnel be required to disclose certain types of outside interests as part of the grant award process, as presently under consideration by NIH and NSF. It also recommended the NSF and NIH take a number of additional steps to effectively manage potential conflicts of interest and to address the extent to which U.S. and foreign industrial liaison members can be given advance access to research the agencies have funded.

GEORGE H. DUMMER

VICE PRESIDENT FOR INFORMATION SYSTEMS

In recent years, Information Systems (IS) has become increasingly adept at absorbing organizational and technological change without disrupting services to the Institute community. This experience proved critical to the success this year of several complex transformations:

- Merger into IS of the Project Athena service delivery functions and the associated reorganization and relocation of over half the IS staff.
- Transition of the Athena computing environment's 1,200 machines from sponsor-supported hardware acquisition and maintenance to central and departmental Institute funding.
- Installation of a major upgrade to the 5ESS digital switch hardware and software, enabling telephone services to continue in the event of a cable disruption between the host switch site in Building E19 and the two auxiliary sites.
- Replacement of the two central mainframe computers in the MIT Data Center with one larger machine.
- Formation of the Distributed Library Initiative, a new joint undertaking with the MIT Libraries to revolutionize the delivery of electronic library services to the MIT community.
- Introduction of a new planning process for administrative computing in which all the central administrative offices at the Institute participated, resulting in a consolidated plan for administrative computing for 1993–97.

Two new appointees joined the IS senior management team which led the organization through these transformations: Daniel M. Weir, Director of Computing Support Services, and Dr. Gregory A. Jackson, Director of Academic Computing.

Despite the internal upheavals, IS services to the Institute community improved in every area:

- Faculty and students who use academic computing found Athena more reliable, with a more friendly interface, running on more commercial versions of UNIX, and with more third-party software and new services.
- Telephone service customers saw reduced long-distance rates, new flat fees for jack installations, and no general rate increase for 1992 or 1993, all evidence of successful efforts to contain costs.
- Administrative computing clients benefited from work done on 40 software development and maintenance projects, from expanded training opportunities and from improved mainframe connectivity and capacity.
- People who shop at the MIT Computer Connection (MCC) found an expanded product line of DEC and NeXT workstations in addition to Apple, IBM, and Dell microcomputers.
- Researchers and other members of the MIT community subscribed to new Sun software library services and to new maintenance agreement offerings for workstations, all at more substantial discounts than otherwise available.
- The entire MIT community became aware of the importance of complying with software licenses through an IS education campaign against software piracy. Tools were distributed for auditing software installed on Macintosh and DOS computers and for maintaining office records of software acquisitions.

At the same time, demand for IS services grew by almost every visible metric. A few examples:

- In the spring term, 5,000 faculty and students used the Athena Computing Environment each day, an increase of 10 percent from the fall. More than 25 percent of the total MIT community now use Athena services on a daily basis.
- Sales at the MCC for fiscal 1992 were $11,887,229, up 8 percent from 1991. The number of computers on MITnet grew to 5,000. Requests for network drop installations and for consulting assistance increased proportionately.
- The number of databases supported by the MIT Data Center grew from 30 in 1991 to 44. Electronic-mail traffic flourished, from 14,500 messages delivered per day in March 1991 to 29,800 in March 1992. In the third quarter, TechInfo, the public information service, logged over 300 sessions a day, up from 200 a day the previous quarter.

- Unusually high growth in the number of digital telephone lines early in fiscal 1992 resulted in a 5 percent increase for the year, higher than the anticipated level of 3 percent.

This year, IS also maintained attention on important ongoing initiatives:

- The Intellectual Property Counsel worked within IS, with the Office of Sponsored Programs, with the Technology Licensing Office, and with faculty and staff throughout the Institute to negotiate terms and conditions of research agreements, software licenses, and other third-party contracts. The volume and complexity of agreements have become so great that an Assistant Intellectual Property Counsel will be appointed in fiscal 1993.
- The Information Security Office coordinated the review by the Institute's Emergency Response Team (ERT) of Functional Area Recovery Management (FARM) plans for central departments. ERT is planning a full scale mock disaster test in the fall. The office worked with the Institute Archives to survey all departments about their needs for off-site storage of records in all forms.
- In addition to monitoring progress on key software development and installation projects, such as the student and personnel systems, the Administrative Computing Steering Committee sponsored a new planning process for administrative computing. All central departments participated. Coordinated by the Administrative Computing Resource Management (ACRM) group, the process included a daylong working session for Administrative Council, system managers, and administrator officers (AOs) in academic departments and research centers. ACRM made several recommendations for fiscal 1993 to the Steering Committee, which were approved. The recommendations include:
  - Formulate a vision for the business operations of MIT and link the administrative computing mission to it.
  - Extend the scope of planning for administrative computing beyond the central offices.
  - Coordinate data administration and empower the AO Advisory Group to drive data accessibility efforts.
  - Create incentives for departments to coordinate computing activities.
  - Develop an architecture for administrative computing.

As the year comes to a close, IS is launching initiatives with the potential for major future impact:

- In fiscal 1993 the Institute is beginning a long-term effort to renew the Athena equipment base, with the goal for the steady state to have no Athena workstation more than four years old. Achieving the goal requires acquiring and deploying some 300 computers per year from now on, a complex annual undertaking.
- IS announced the formation of a new Database Services group in Administrative Systems Development, bringing together staff from several groups who have been supporting databases for administrative clients on a range of hardware and software platforms.
- Kathleen R. Cibotti has been appointed Director of Administrative Systems Development to succeed Donald E. Heller, who is leaving the Institute to pursue doctoral studies.

IS has worked hard to become an organization which delivers outstanding customer service, an organization where staff have a satisfying and challenging work environment, an organization widely recognized as a leading contributor to MIT's excellence. IS is closer to achieving those goals than ever before, but the organization must do even better in the years ahead. This year the IS senior management team investigated the philosophy and practice of Total Quality Management (TQM). The team came to believe that involving the organization in TQM can boost its ability to achieve a vision of exceptional customer service, exemplary staff contributions and development, and careful management of Institute resources. In June Professor James D. Bruce, Vice President for Information Systems, announced to the entire staff that the IS directors had decided to make a serious commitment to a long-term TQM effort. Information Systems has already started moving. TQM is the way IS will approach its program priorities for fiscal 1993. This process promises to be a learning experience for all of us.

JAMES D. BRUCE

Academic Computing Services

With the merger of Project Athena's service delivery functions into IS, Academic Computing Services (ACS) was formed this year to promote and enable effective use of information technology in MIT education and scholarship. ACS staff total eight, organized in three subdivisions:

- *Educational Planning and Support.* The manager and faculty liaisons assist faculty with educational technology, publish *The Athena Insider,* and evaluate and implement solutions to educational problems.
- *The Visitor Center.* The information officer operates a state-of-the-art demonstration facility where interested parties within and outside MIT learn about academic computing.
- *Director of Academic Computing.* The Director coordinates academic computing activity across the Institute and represents MIT in national educational computing organizations.

ACS, which receives most of its funding from the Provost, manages service-level agreements with other IS departments to operate, maintain, and provide support for the Athena Computing Environment. ACS works closely with the Center for Educational Computing Initiatives (CECI) and with the faculty Academic Computing Council, which provides policy guidance for both CECI and ACS.

MIT's primary academic computing resource is the Athena Computing Environment, a network-based system of 1,000 client workstations and 200 server machines. This year brought several enhancements to this world-renowned educational resource:

- *IS reorganized the process for improving Athena.* Interdepartmental teams now appraise ideas for improvement, propose specifications, develop or acquire software, implement changes in the field, and provide support to users affected by the changes. This process enhances the usefulness of Athena and its compatibility with other services.
- *IS added new services to Athena.* Two examples are especially interesting: Online With Libraries (OWL) and the Student Information Service (SIS). Based on the On-Line Consulting and On-Line Teaching Assistant services, OWL puts faculty and students in touch with reference librarians. From SIS, Athena's first administrative application, students can see their academic records and update parts of their own biographic data.
- *ACS continued to expand Athena's third-party software and tools.* The Statistical Analysis System (SAS), the cT authoring language from Carnegie Mellon University, the Xess scientific spreadsheet, and the Maple mathematical program are recent notable additions.
- *Electronic classrooms improved dramatically.* IS brought into service a pilot Macintosh installation in Room 6-218M and a major new facility in Room 1-115, with 22 student DECstations and a video-projected faculty DECstation in fully refurbished space. ACS also upgraded projectors in other electronic classrooms, and is participating in redesigning and equipping Rooms 1-390 and 6-120.

Several ACS activities this spring set the stage for the year ahead:

- *IS began a long-term effort to renew the Athena equipment base.* The goal for the steady state is to have no Athena workstations more than four years old. Athena equipment renewal has three aims: replace outdated public workstations, replace and upgrade servers, and, within limits and under specific conditions, assist academic departments to improve MIT education. Through an RFP and competitive bidding, IS purchased over 200 workstations from Digital Equipment Corporation, to be followed later this year by over 40 workstations from IBM Corporation. ACS is working closely with other IS units in this effort
- *ACS met with department heads to explore educational computing.* Results of these meetings thus far include plans to participate in one of the Biology 7.01n prototypes and a broad initiative with social science departments to greatly expand instructional use of SAS statistical software.
- *ACS will upgrade the Macintosh pilot classroom.* With support from the School of Science and the Committee for Review of Space Planning (CRSP), this summer ACS will increase the number and power of the cluster Macintoshes and make the cluster publicly available without a staff attendant. If this is successful, it will become possible for ACS to offer much more diverse public academic-computing facilities in the future.

This spring ACS staff redefined the priorities which influence the allocation of their efforts, the substance of Athena software improvements, and the Athena equipment renewal program. ACS assigns higher priority to educational initiatives with four properties:

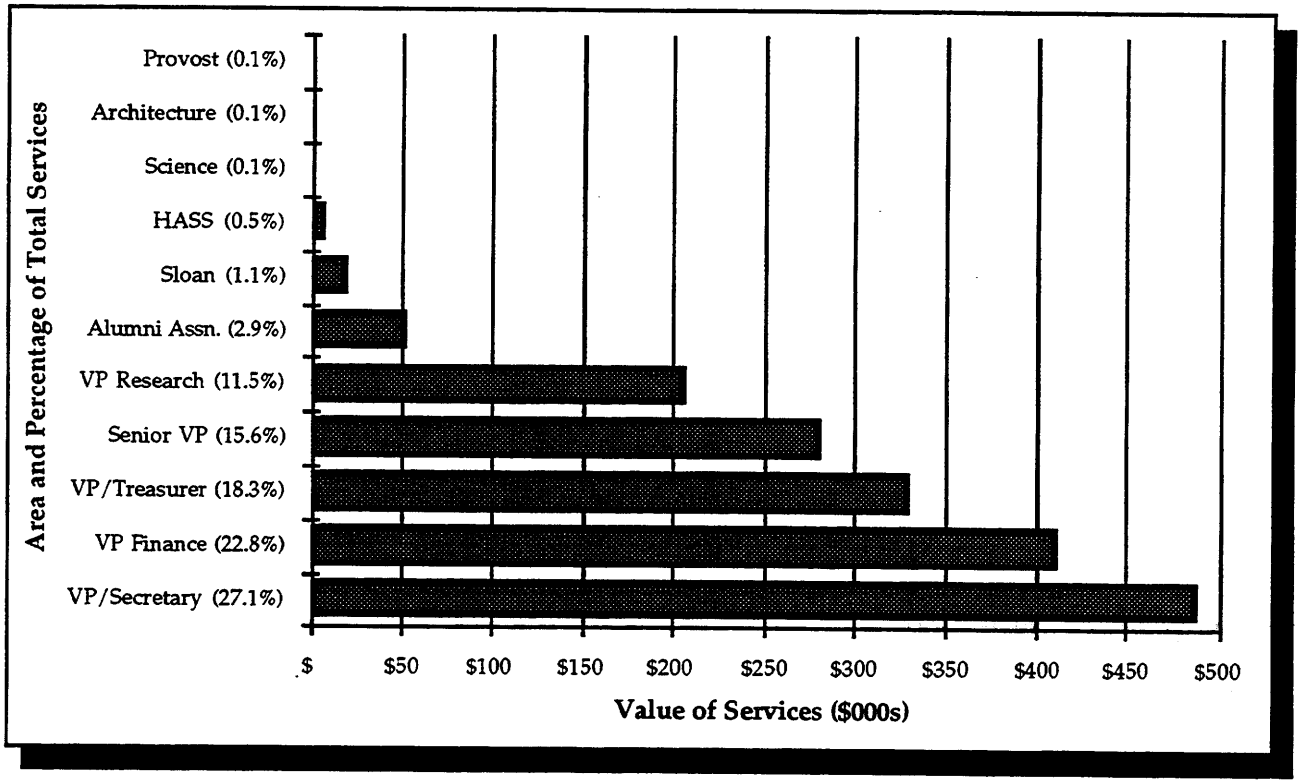
- *Focus* — initiatives that involve the General Institute Requirements, including required subjects and popular distribution or humanities subjects, and introductory subjects in the larger Courses.
- *Reach* — initiatives that involve large numbers of undergraduates.
- *Innovation* — initiatives that solve long-standing educational problems in new ways or that expand education and innovate in other creative ways.
- *Equity* — initiatives from departments whose access to educational technology is limited.

The continuing challenge for ACS is to achieve balance among three sometimes competing demands: energetic promotion of educational computing, attentive management of existing courseware and educational projects, and effective response to daily crises, problems, and inquiries. This year has brought dramatic improvement in each domain. ACS is working hard to ensure comparable progress in the year ahead.

GREGORY A. JACKSON

Administrative Systems Development

In 1992, Administrative Systems Development (ASD) continued its mission to provide application development and related services in partnership with administrative units that support MIT's research, educational, and business needs. ASD continued to expand its activity with administrative units in the schools and research sectors of the Institute. Building from 8 percent in 1991, about 13 percent of ASD's services were provided to departments in the schools and research areas in 1992. Allocation of ASD services is shown in the chart below.



1992 ASD Services by Senior Officer (excluding Information Systems)

Working with its clients, ASD achieved a number of important project milestones:

- *Technology Licensing Office (TLO) System, Release 2.* This release, which includes the automation of the royalty distribution processes, will streamline how TLO pays royalties to the hundreds of inventors at MIT.
- *Property Inventory and Accounting System, Release 2.* The Property Office uses the system to inventory and calculate the depreciation of all the equipment owned by MIT and its research sponsors. The Property Office expects to cut over completely to the new release in the fall, after parallel operations this summer.
- *Student Information Service (SIS), Release 1.* This client/server-based system was a collaborative effort between ASD, the Registrar's Office, and Distributed Computing and Network Services. Using any Athena workstation, students can now make inquiries about their schedule and grade information, change parts of their basic biographical data, and consult the entire MIT course catalog and class schedules. This system is a model for how IS will develop secure administrative applications using a client/server architecture in the future.

The IBM mainframe applications received significant attention this year. For example:

- As the Campaign for the Future entered its final year, the Alumni, Donor, Development, and Schools system was enhanced to allow donors to make payments to the Institute via electronic funds transfer directly from their own bank accounts. This feature greatly reduces MIT's paper processing for payments formerly made manually and simplifies the giving process for donors. Over 100 donors have already used the service to

donate over $10,000 through June 1992.

- Programming was necessary to respond to a Medicare second-payer audit conducted by the federal government. This audit reviewed current and former MIT employees for individuals on Medicare who would have been eligible for health insurance from MIT. While other universities had to file for extensions to submit their responses, ASD and the Benefits Office completed the work ahead of schedule, avoiding fines that could have totaled up to $1,000 for each of the over 800 individuals on the audit list.

ASD embarked on a number of personal computer–based development projects, such as:

- A project to automate the processing of admissions applications for the Sloan School of Management S.M. (master's) program. This system will run on a Macintosh computer in the S.M. admissions office.
- A project with the IS finance team to develop a Management Financial Report system, also designed to run on a Macintosh. This system will provide a standardized financial management, budgeting, and reporting tool to be used by all IS offices.

Business analyses were completed for Physical Plant and begun for Telecommunications Systems. An opportunity evaluation of the information systems needs of the Deputy Treasurer's office was completed. ASD also began work with the MIT Libraries on a preliminary analysis to define a new library operations system. The analysis, which will focus on finding a package solution to meeting the acquisition, cataloging, and circulation management needs of the Libraries, will be completed in fiscal 1993.

In addition to the 40 projects that ASD managed in 1992, a team of ASD managers worked with the Audit Division and the Director of Information Systems Planning to investigate data administration for MIT. The team's work revealed that people throughout the Institute need more effective ways to locate the administrative data they need and to coordinate data definitions across systems. The team's recommendation to work with a few departments to prototype a coordinated data dictionary/repository service was approved by the Administrative Computing Steering Committee.

ASD will continue to work closely with its clients and other IS service providers to deliver reliable, efficient, and effective information systems to help the Institute meet its business needs.

DONALD E. HELLER

Computing Support Services

Over the past year Computing Support Services (CSS) has increased its customer focus. CSS customers include the entire Institute: faculty, students, and administrative and research staffs. The CSS mission continues to be delivery of end-user computing support services to the Institute, including the sale of computing equipment and services, training, consulting, publications, and software acquisition. These services are provided through a customer service vision:

> CSS is committed to providing predictably positive experiences for our customers by consistently meeting or exceeding their expectations. Our goal is to offer expert service with a personal touch.

While providing exemplary customer service, CSS has built and seeks to maintain an enthusiastic and dedicated professional staff by promoting a nurturing and productive work environment focused on individual goals and career development. CSS continued to expand its range of products and services delivered to the Institute this year through the following five teams:

- *MIT Computer Connection.* The Microcomputer Center changed its name to the MIT Computer Connection (MCC) in this, its eighth year of operation. This change reflects the fact that the MCC now sells DEC and NeXT workstations in addition to Apple, IBM, and Dell microcomputers. The MCC participated in the Athena equipment renewal process with Distributed Computing and Network Services and Academic Computing Services, and it sells aggressively priced Athena workstations through the Purchasable Workstation Program. In 1992, the MCC completed negotiations with Sun Microsystems to begin selling their workstations and had preliminary conversations with IBM and Hewlett-Packard regarding their workstation lines. Sales for fiscal 1992 are $11,887,229, up $885,213 from 1991. The MCC inventory continues to be managed with great precision, with eight turns of inventory this year and negligible shrinkage or obsolescence. The MCC received a clean bill of health following a three-phase study by the Audit Division covering inventory, electronic data processing procedures, and general business operations. The MCC also had a two-phase renovation, making new space for the Computer Services group and improving the appearance and efficiency of the sales floor.
- *Consulting.* With 11 full-time staff and approximately 40 part-time student employees, Consulting provides microcomputing and Athena technical support, consulting, and user accounts services. Help is provided on-line, by phone, and in person; it is available to all members of the MIT community who use microcomputers and Athena workstations. Members of the Consulting group work collaboratively with other groups within CSS and IS, as well as with other technical support groups and help desks. Members assist with and participate in many of the two dozen user and local expert groups meeting monthly on campus. CSS Consulting also provides adaptive technology recommendations and solutions through the Access Technology for Information and Computing (ATIC) Lab.
- *Computer Services.* Computer Services was formed by combining the VAX Resource Center, a support organization for DEC and Sun computer users, with PC Service, a hardware repair facility for Apple, IBM PC, and NeXT computers. The new organization provides a variety of postinstallation hardware and software support services to a diverse constituency of MIT students, faculty, and administrative and research staff, both on campus and at Lincoln Laboratory and other remote sites. During fiscal year 1992, Computer Services provided discounted hardware maintenance for approximately 1,100 Athena CPUs, 400 other DEC CPUs, and 150 Sun Microsystem CPUs through service contracts with maintenance vendors. Computer Services also repaired approximately 2,200 Apple CPUs, 200 IBM CPUs, and 50 NeXT CPUs. On the software side, Computer Services provided software updates and technical assistance for 350 DEC CPUs and more than 225 Sun CPUs. Fiscal year 1992 revenue for Computer Services, a 100 percent cost recovery organization, is forecast at $2.2 million.
- *Software Acquisition.* The Software Acquisition group was officially one month old at the beginning of this fiscal year, combining resources and services previously provided by IS and Athena. Software Acquisition reviews, negotiates, and approves all vendor software license agreements, in conjunction with MIT's Intellectual Property Office and Department of Purchasing and Stores. In the latter part of the year the group, working with the Director's office, began a restructuring in order to increase the number of licenses it could process and decrease the turnaround time involved in each review. Software Acquisition began hosting vendor demonstrations this year for specialty software products. Compared to last year, the group is

responsible for twice as many products, all offered to the MIT community at greatly reduced prices. Software Acquisition also began an awareness campaign to educate MIT staff and faculty in the proper execution of software license agreements. Additionally, Software Acquisition was involved in the IS task force coordinating the campaign against software piracy and continues to assist departments and groups in meeting the requirements of their software licenses.

- *Training and Publication Services.* Training and Publication Services combines two functions: Training Services and Publication Services. This year Training Services provided hands-on courses on microcomputer and mainframe topics and use of self-paced materials to over 2,000 faculty, staff, and students in the IS Training Lab. The monthly seminar series — attended by over 2,500 community members — included user group meetings for popular software products, Quick Start demonstration classes for new microcomputer users, the Brown Bag Theater video series, and a wide variety of vendor demonstrations. Over 2,200 MIT students attended Athena minicourses (one-hour lectures offered on 10 Athena related topics). Special minicourses were offered on request and included those presented to MITES and Interphase students in the summer.

  Publication Services continued to provide the MIT community with a wide variety of free computer-related documents, including user guides, technical memos, quick guides, and reprints. Ten issues of the *i/s* newsletter were produced, including an insert on software piracy *(Of Piracy, Copyrights, and Software Audits)*. A folder of pertinent information on the Athena Computing Environment, including the booklet *Welcome to Athena,* was distributed to new students and all faculty members. Documentation and publicity support was provided to other IS organizations, including Academic Computing Services, Distributed Computing and Network Services, Operations and Systems, and Telecommunications Systems. During the past year, documents produced by Training and Publication Services received three awards: one from the Society for Technical Communication and two from the ACM Special Interest Group on University and College Computing Services.

DANIEL M. WEIR

Distributed Computing and Network Services

Distributed Computing and Network Services (DCNS) was established on July 1, 1991, a merger of Network Services with Project Athena's operation and development activities. The DCNS mission is to provide a campus-wide distributed computing infrastructure that supports education, research, and administration. DCNS has responsibility for key elements of MIT's distributed computing infrastructure:

- MITnet, the campus-wide computer network.
- The Athena Computing Environment, including software development and operational support of servers, workstation clusters, and Athena workstations in private offices.
- A common set of network-based applications and on-line services for supported computer platforms including Macintosh computers, DOS-compatible computers, and UNIX workstations.

This year DCNS focused on building a new team and culture while continuing to deliver quality services to customers. This culture building included establishing the "orange process," a common framework and terminology for software development activities to ensure the quality of DCNS products and services.

Progress continued toward the goal of universal network access, as expansion of MITnet, the campus computer network, continued at a fast pace. Accomplishments include:

- The number of computers on MITnet grew to 5,000. On an average day, the network now delivers over 30,000 electronic-mail messages through the DCNS central mail hubs. Total traffic on the network spine increased by over 50 percent during the year measured in terms of average packets per day. The MITnet client base now includes most MIT departments and research groups. The Athena Computing Environment continues to be a primary client. An increasing number of administrative offices joined MITnet this year.
- The growing importance of the network to MIT makes it critical to install technology which is reliable and allows the small technical staff to quickly isolate and rectify problems. DCNS completed migration to the new FDDI spine and upgraded major subnets to support the simple network management protocol (SNMP), an emerging industry standard which allows for the remote management of critical network hardware.
- DCNS consultants coordinated over 300 network installation projects, ranging from networks for entire departments to network connections for single machines and including both Ethernet and LocalTalk. Use of the unshielded twisted pair Ethernet (UTPE) service grew: over 550 UTPE network drops were installed connecting over 900 machines to MITnet, including some in classrooms and public areas. UTPE exceeded its financial targets, which will enable DCNS to reduce the price of the service in the coming year.
- MITnet was extended to several new buildings including Alpha Phi sorority, and Buildings E39 (MIT Press) and W59 (Alumni Association). New Ethernets were installed in Buildings 20, N42 (Graphic Arts), E56 (Sloan), W71 (Next House), and E51/52/53. Most nonresidential campus buildings are now connected. A key priority for the future is to obtain funding to extend network services to the student residences.
- This year DCNS added support for AppleTalk routing service on MITnet. AppleTalk service is used by a number of offices including the Alumni Association, Dean for Student Affairs, and IS. This new service allows these groups to easily share files and printers between offices across campus.

This year DCNS assumed responsibility for operating the Athena Computing Environment. Under a service-level agreement with Academic Computing Services, DCNS operates servers, manages public workstation clusters, deploys equipment, offers hotline support for departmental workstations, and maintains and develops software.

- During the spring 1992 term, 5,000 faculty and students used the Athena Computing Environment each day, an increase of 10 percent from the fall term. More than 25 percent of the total MIT community now use Athena services on a daily basis. The Athena system currently supports nearly 200 servers and 1,000 workstations located in 15 public clusters, 30 departmental clusters, five student residences, and hundreds of offices.
- In 1991 IS deployed over 100 new workstations with the last of the Athena hardware grants from DEC and IBM, replacing the oldest workstations. In the spring 1992 the Provost approved funding for an annual Athena equipment renewal process based on a four-year life cycle for equipment. Early in the summer of 1992 DCNS

received initial shipments of the new workstations and began deployment in public clusters. The new workstations provide Athena's first significant infusion of color monitors.

- DCNS worked with Academic Computing Services and Computing Support Services on the release of two new versions (7.3 and 7.4) of the Athena Computing Environment software, adding three new supported platforms and vendor operating systems (IBM RS6000/AIX, Digital DS3100/Ultrix and Digital DS5000 Model 25/Ultrix). A major conversion of the Athena file system from NFS to AFS will be completed during the summer of 1992 and noticeable to students when they return in the fall. Operational monitoring began within Athena, including a "daily report" on Athena systems status, real-time monitoring of workstation usage patterns, and the analysis of summary operational statistics.
- DCNS maintains public computing facilities in approximately 15 public areas across the campus. Maintenance of facilities used by thousands of students a day is an on-going challenge. Make-overs of many Athena public clusters were completed this year.
- With Computing Support Services, DCNS began the Athena purchasable workstation program, giving departments the opportunity to purchase Athena-compatible workstations at the MIT Computer Connection and to purchase access to Athena software and support from DCNS for an annual service fee.
- With Computing Support Services, DCNS renegotiated the Athena hardware maintenance service contracts. Bell Atlantic was selected to service IBM RS6000 workstations and servers. Digital Equipment Corporation will continue to service Athena's DEC equipment.

Efforts to provide value-added network-based services for Macintosh, DOS, and UNIX workstations continued. As more people connect to MITnet, demand is growing for on-line access to network-based services, including communication tools such as electronic messaging, mail and conferencing; electronic directories; library information including full text documents; and services such as authentication and authorization. Services DCNS developed, such as TechInfo and TechMail, are now in use at other universities. Activities included:

- *TechMail.* Use of TechMail, the Macintosh electronic-mail facility, increased with as many as 800 to 900 persons using it regularly. DCNS released TechMail V2.0 with significant new features, such as document enclosures and standard Athena services such as Kerberos and Hesiod. In the summer of 1992 DCNS will begin field testing TechMail for Windows, the first of a series of network-based products for MIT's DOS community.
- *MacZephyr.* This software, currently in field test, is based on the Athena zephyr software and provides instant messaging functionality to Macintosh users.
- *MacDiscuss.* Currently in field test, this is based on the Athena discuss software and provides conferencing and bulletin board functionality to Macintosh users.
- *TechInfo.* DCNS released TechInfo V3.0, with enhanced functionality, including world-wide TechInfo, linking to TechInfo servers at other sites. Client software is available for the Macintosh and Athena workstations. Provider software allows information providers to input and maintain their contributions to the service.
- *MITDIR.* The on-line staff and student directory, MITDIR receives 1,800 electronic requests per day. Client software exists for Macintosh computers, UNIX workstations, and the IBM mainframes. DCNS began an effort with the Communications Office to upgrade service in the coming year to include MIT departmental listings.
- *Student Information Service (SIS).* With the Registrar's Office and Administrative Systems Development, DCNS undertook a project to provide Registrar data to students using Athena workstations, the first MIT administrative application to utilize Athena technology.
- *Forms routing.* DCNS initiated a project to develop a general forms-routing function based on the Athena client/server architecture. With a requirements document completed, the project is now in design. DCNS will continue to work closely with key administrative offices to build a prototype and to further refine requirements.
- *Distributed Library Initiative.* In conjunction with the MIT Libraries and the Office of the Vice President for IS, DCNS is supporting the initiative to bring commercial databases and electronic journals on-line. In 1992 DCNS evaluated BRS/Search and deployed an RS/6000 for testing and prototyping new library services.

CECILIA R. d'OLIVEIRA

Operations and Systems

The Operations and Systems (O&S) mission is to provide a central computing facility and technological leadership that deliver efficient, high quality computing services in a distributed computing environment that supports the Institute's business needs. O&S activities can generally be categorized as installation, maintenance, and client support. O&S offers general purpose computing on one large IBM computer and provides training and consultation to the IBM client community. Additionally, O&S provides facilities management services to Institute departments to assist them in maintaining dedicated computer systems. Computers managed under such arrangements include the MIT Supercomputer Facility's Cray 2, a DEC 8850 for Accounts Payable and Purchasing, a DEC 8530 for Physical Plant, a DEC 9420 for Academic Computing Services, and others.

Selected accomplishments which had a direct impact on O&S clients include:

- O&S worked with the Administrative Computing Resource Management group (ACRM) to better manage the costs, usage, and capacity planning for administrative computing.
- As part of a review of the capacity and capabilities of the IBM mainframe computers operated by IS, ACRM recommended that MIT purchase an IBM 9121-480 central processing unit (CPU) to replace the IBM 3090 (MITVMC) and 3083 (MITVMA) computers. After the ACRM recommendation was approved by the Administrative Computing Steering Committee, the new CPU arrived on May 26, 1992, and operationally replaced MITVMA on June 6 and MITVMC on June 13.
- Other new equipment installations requested by clients included:
  - A Cray X-MP/EA (ED), which replaced the Cray 2, for the MIT Supercomputing Facility.
  - A DEC VAX 9420 (PATRIOT) used as part of the Athena Computing Environment.
  - A Network Switching System to connect MITnet/NEARnet to NSFnet.
  - A DEC VAX 6510 (MITSIS) for the new Student Information System.
- The XEROX page-printing technology was converted to IBM Advanced Function Printing (AFP) laser-printing. This conversion provided greater printer functionality at existing sites, and introduced a new laser printer to E19.
- A new SQL/DS support service was introduced in response to client application needs in two departments, the Comptroller's Accounting Office and the Student Financial Aid Office.
- O&S expanded and improved client services, for example, by:
  - Conducting over 20 courses in client departments.
  - Increasing the number of mainframe courses in the training lab, at a lower cost to clients.
  - Improving connectivity from the microcomputer to the mainframe.
- Client user groups have been expanded to address a wider audience. Participation at the IBM Mainframe User Forum steadily increased over the last year, an SQL Programmers' Lunch was held on a quarterly basis, and an ADABAS user group will be started in the first quarter of fiscal year 1993.
- As part of the ongoing effort to provide better services to clients, O&S began efforts to conduct another client satisfaction survey. The previous survey was used to initiate many of the current service enhancements, and it is anticipated that the new survey will result in additional initiatives.
- O&S completed the first edition of W91 business continuity plan.
- Computer Printing and Media Services has added a Macintosh-based color scanner and scanning software to its self-service operation in Room 11-226.

The chart below provides an overview of MIT's Data Center.

STATISTICS FROM MIT'S DATA CENTER

Category	FY 1992	FY 1991
Disk capacity:	130 gigabytes	128 gigabytes
Registered users:	6,487	6,500
Tape mounts:	100,000/year	100,000/year
Pages printed:	17,000,000/year	19,000,000/year
Supported databases:	44	30
Largest database:	5.7 gigabytes	4.5 gigabytes
Production jobs (for jobs controlled by O&S only):	36,000/year	36,000/year

Production Machine	Cycle Capacities	DASD (Formatted)	Registered Users
ED	1 GFLOPS	31 gigabytes	2,034
VAX (Admin)	39 VUPS	24 gigabytes	1,888
MITVMA and C	40 MIPS	65 gigabytes	2,553
PATRIOT	80 VUPS and 250 MFLOPS	10 gigabytes	12

Notes

VAX (Admin) includes EREQ, MITPPL, MITVAPS, MITVBUD, PERSON, and MITSIS
MIPS = million of instructions per second
VUPS = VAX unit of performance (roughly equal to MIPS)
FLOPS = floating-point operations per second
MFLOPS = million of floating-point operations per second
GFLOPS = billion of floating-point operations per second
gigabytes = billion of characters

ROGER A. ROACH

Telecommunications Systems

In December 1991 Telecommunications Systems upgraded the 5ESS generic software from version 5E4.2 to 5E5.1. The upgrade was the first phase of a two-phase effort which is scheduled to be completed with the introduction of new firmware in December 1992. The current enhancement enables the three on-campus switch sites to stand alone and to continue to function in the event of a cable disruption between the switch sites and the host site in Building E19. In addition, the 5ESS modem pool was expanded to support high speed modem pooling, and the associated Octel Maxum voice-mail system was enhanced to ensure service stability and compatibility with the 5ESS enhancement.

In 1990 Telecommunications Systems entered into a strategic partnership with AT&T, a partnership that includes several long-term agreements. In 1991 an additional agreement was added to cover the processing of long-distance telephone calls. MIT will see a cost avoidance of $1.7 million over the duration of this four-year agreement. Lincoln Laboratory, as a party to the agreement, also benefits.

The MIT community saw evidence of this cost avoidance with a 10 percent reduction in long-distance service rates. The October 1991 rate reduction announcement included a notification of a new flat rate for 5ESS jack installations, which will result in an average savings of about $100 per jack. Local telephone rates also were restructured, resulting in a 10 percent reduction in the average cost per local telephone call. General telephone rates in fiscal year 1992 were held at fiscal year 1991 levels. No rate change is planned for fiscal year 1993.

In March 1992 the department learned that Cincinnati Bell Information Systems (CBIS), the supplier of MIT's ICE-9 integrated telecommunications management system, had elected to discontinue support for the product. Subsequent negotiations between MIT and CBIS resulted in an agreement whereby CBIS will continue to provide support of MIT's system until December 31, 1992. During this time MIT will assume greater responsibility for self-support of its system as its expertise increases through a technical knowledge transfer from CBIS to MIT personnel, especially those in Administrative Systems Development and Telecommunications Systems.

The Institute's Emergency Response Team accepted the department's 5ESS Functional Area Recovery Management (FARM) plan in May 1992, for inclusion in MIT's overall business continuity plan. In line with this plan, some of MIT's long-distance telephone traffic will be diverted to MCI for processing in order to provide an alternative if the primary carrier, AT&T, has a failure in its network. This approach eliminates MIT's total dependence on one carrier.

New cabling and wiring were installed to provide telephone and data services for the Plasma Fusion Center in Building NW22 and for the Office of Facilities Management in Buildings E28 and E56. 5ESS service was extended to Edgerton House (NW10). A T-1 facility was leased from New England Telephone to provide connectivity to Alpha Phi's switching system. Additional FDDI (fiber distributed data interface) linkages to MITnet were installed, as well as numerous UTP (unshielded twisted pair) Ethernets and other network connections.

A number of videocasts via satellite were made this past year, including the participation of one speaker from Geneva in the ILP October 1991 symposium on computers and telecommunications. Video teleconferencing (VTC) was introduced into the daily activities of the Leaders for Manufacturing Program in October 1991 when a PictureTel system was installed in Room E40-290. Since then VTC has been used in a number of events, such as a recent international chess conference involving participants in Paris and at MIT and Harvard University.

Departmental personnel participated in a number of programs focusing on customers, for example, quality customer service and professional telephone skills. Workshops on improved communication skills were held for departmental management in the summer of 1991. Following the workshops several managers participated in an interpersonal skills program. Departmental management and staff were introduced to total quality management (TQM) tools, which are now being used by a number of work groups on issues such as training and telephone console operations.

MORTON BERLAN

VICE PRESIDENT AND TREASURER

INTRODUCTION

The *Campaign for the future* reached a successful conclusion at the end of the year and raised $710 million of gifts and pledges, exceeding the goal of $700 million. The Campaign total exceeded by 29% the original goal of $550 million announced at the Campaign Kickoff on October 22, 1987 in Cambridge.

In March of 1990, the Corporation voted to increase the goal by $150 million when it became apparent that the original goal would be reached about 1 1/2 years early. The environment for giving became less favorable after that announcement because of the crisis in the Middle East and the economic recession, which was particularly adverse in New England where about one-fourth of our individual donors live.

Fortunately, we were able to maintain much of the momentum of the Campaign despite these problems and exceeded the goal a few weeks before the official ending of the Campaign. In the final months, the Campaign benefited from the renewal of memberships in the Leaders for Manufacturing Program and favorable commitments from a number of alumni who waited until near the completion of the Campaign to make their commitments. The Campaign also benefited from new commitments from donors who had already made generous commitments to the Campaign. These included the Martin Foundation of Elkhart, Indiana, the Edwin S. Webster Foundation of Boston, and the Alfred P. Sloan Foundation of New York.

The Campaign's successful results reflect the important activities of the three senior officers: Chairman Paul E. Gray, President Charles M. Vest and Provost Mark S. Wrighton. Their leadership and participation in soliciting gifts finally brought the Campaign to completion. The involvement of Carl Mueller, Reid Weedon and other key volunteers made a real difference. Finally, the efforts of the faculty and staff at MIT exceeded our expectations. Significant time now is being devoted to planning the Campaign celebration events, and post-Campaign activities and fundraising. In addition to the ongoing activities, the first few years after the completion of the Campaign should be used to develop the knowledge and fundraising skills of the staff through education and training programs.

The number of professional staff of Resource Development and the Industrial Liaison Program remained stable during this final year of the *Campaign for the future.* There were six staff promotions (4 women-67%, 2 men-33%) including one Black American woman, and four promotions of women from support positions to the administrative staff. Included among these promotions, Karl Koster became Director of Corporate Development in the Corporate Relations section, and Sarah Carothers and Dianne Goldin were named Associate Directors of the National Campaign Office. Effective June 1, 1992, Ms. Carothers transferred to the School of Science as its Director of Development. There were four new hires during the year (2 women and 2 men), filling open positions resulting from resignations or transfers. On July 1, 1992, Stephanie Harriston-Diggs joined Resource Development as a District Director after completing the Case Minority Internship Program designed to attract minority professionals to

institutional fundraising. Effective September 1, 1992, Royce N. Flippin, Jr., Director of Athletics at MIT for the past 12 years, will join the Resource Development staff on a part-time basis as Director of Program Advancement, working on selected fundraising programs and projects.

Private Support

Private support for Fiscal Year 1992 totaled $97.4 million, including the following: $89.6 million in gifts, grants, and bequests, and $7.8 million in support through membership in the Industrial Liaison Program. The total compares with $101.1 million in 1991, $111.1 million in 1990, $86.9 million in 1989, and $91.9 million in 1988. Gifts-in-kind for the past year (principally gifts of equipment) were valued at $5.4 million.

Sources of gifts for Fiscal Year 1992 were: alumni, $28.7 million; non-alumni friends, $6.4 million; corporations, corporate foundations, and trade associations, $31.7 million; foundations and charitable trusts, $22.0 million and others, $0.8 million.

Donors designated expendable and endowed funds as follows: unrestricted, $11.4 million; departments, $36.7 million; faculty salaries, $13.9 million; graduate student aid, $9.7 million; undergraduate student aid, $7.1 million; building construction funds, $2.0 million; and other funds $8.8 million.

Private support in 1992 increased the commitments raised for the *Campaign for the future* to $710 million, representing 101% of the $700 million goal set for June 1992. By Campaign priority, commitments raised and percentage of goal achieved were the following: Endowment for Faculty Chairs, $103.8 million (94%); Academic Programs, $337.8 million (112%); Student Support, $116.1 million (96%); New and Renovated Facilities, $18.7 million (26%); and Unrestricted Gifts, $108.9 million (108%). In addition, commitments totaling $24.9 million are pending designation.

INDIVIDUAL GIVING

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, Chairman, or the members of the Corporation Campaign Committee, regardless of their philanthropic capacity. In addition, the office is responsible for the development process for Campaign prospects in the New York Metropolitan area and Northern California, including San Francisco and Silicon Valley. Major Gifts activity culminated in a large number of solicitations and resolicitations of key prospects. A trip to the Far East by the President and Chairman was coordinated with the Corporate Relations Office, and visits in Japan and Hong Kong were arranged.

The Major Gifts research group prepared 78 solicitation plans, 28 of which represented resolicitations and also produced 124 cultivation plans, numerous prospect profiles, qualification reports, and managed a number of prospect strategy sessions.

Major Gifts concentrated on prospects in the New York Metropolitan area capable of making gifts to MIT of $50,000 or more. The New York Metro team continued its activities in New York City, Long Island, New Jersey, and Southern Connecticut, making calls to identify new prospects and managing cultivation events hosted by area volunteers. The staff made an average of 14 personal solicitations and cultivations each month or a total of 170 during the year.

In fiscal year 1992, the final year of the Campaign generated heightened activity with particular emphasis on the solicitation and stewardship of major donors, and the continued introduction of new senior officers of the Institute. The staff managed 202 solicitation and cultivation visits. In addition, 25 cultivation and stewardship events were held both on and off campus. The objectives of stewardship events are to honor donors as well as effectively cultivate the honorees and other invited guests. The growth and importance of stewardship events is reflective of the need for high level, ongoing recognition of major donors so that a sustained rate of giving can be maintained in a non-campaign environment.

Principal gifts, responsible for prospects capable of making the largest gifts, solicited or resolicited donors for major Campaign support, and coordinated seven events in recognition of major gifts made during the Campaign. The Associate Director for Principal Gifts continued regional major gift responsibilities in Boston, the Midwest, and the Middle Atlantic region, as well as coordinated major gift efforts for the Associate Provost for the Arts and acted as liaison between the wife of the President, Rebecca M. Vest, and Resource Development. These latter activities resulted in 36 cultivation visits, 10 solicitations or resolicitations, and 11 stewardship visits.

Major Gifts assumed responsibilities for all Northern California prospects with the assignment of a Senior District Director to this area in November 1990 and an additional District Director in September 1991. These staff members made a total of 17 trips to California resulting in 125 personal calls on individual prospects. Working closely with area Campaign volunteers, 14 campaign-related events were held, cultivating approximately 200 alumni.

The Major Gifts Office is also responsible for individual donor relations, preparing appreciation letters for the signature of the president and chairman for gifts of $3,000 and above and pledges of $5,000 and above.

Personnel changes included the resignation of Julie Eastman as Assistant Director for Donor Relations in December 1991. She was replaced by Susan Podshadley, who also assumed duties related to the day to day operations of the Corporation Development Committee. Meredith Thomas, District Director, was reassigned to the Northern California area for the last year of the Campaign. Melissa Beasley was promoted to the staff position of Senior Research Analyst.

Corporation Development Committee

The annual meeting of the Corporation Development Committee (CDC) was held in Cambridge on October 29-30, 1991. The group was welcomed during dinner by Chairman Gray followed by remarks by Provost Wrighton and Vice President and Treasurer Strehle.

At breakfast the following day, the meeting opened with an address by President Vest discussing fundraising priorities for the post-Campaign era. Afterward, the group separated for in-depth discussions and evaluation of two of the following issues: Expanding the Base, Restructuring and Redefining the CDC; Formally Organized Fund- Raising: Volunteers for Individuals, Corporations, and Foundations; Involvement: Opportunity for Cultivation and Stewardship at MIT; and Presenting and Promoting MIT. Report summaries of these discussions were made following a luncheon, during which the Dalton Bowl was presented to Charles H. Spaulding for his outstanding volunteer work on behalf of the Institute.

The CDC annual meeting was planned and coordinated by staff members of the CDC Planning Group, headed by H.E. (George) Ramonat, Executive Officer of the CDC

National Campaign Office

The National Campaign Office, under the direction of Acting Director D. Hugh Darden, focused on the solicitation of prospects who could be expected to make gifts of $50,000 - $500,000 during the campaign. Staff throughout the country were strongly assisted in this effort by some 264 volunteers on the National Campaign Committee, under the dedicated direction of D. Reid Weedon, Jr. Assistance was also provided by several current and former members of the Institute faculty and staff. Special attention was given to the Boston area where a Dean's Breakfast Series for leaders of business was initiated in cooperation with the Sloan School. Other cultivational activities included a luncheon for emeritus faculty, a tea at the Brookhaven Retirement Community and several dinners hosted by volunteers. The Boston area volunteer committee, under the leadership of Charles H. Spaulding, contributed importantly to a high level of solicitation activity. Some 75 new prospects were identified and added to the approximately 400 previously identified in the Boston area. One district director was especially assigned to assist in the Northern California area.

The Emma Rogers Society continued to provide opportunities for MIT widows to interact with the Institute. Activities included publication of two newsletters; 3 day-long events on campus, the mailing of an Outreach packet to 450 women recently widowed and numerous committee meetings. *In Memoriam,,* a booklet listing those in whose memory gifts had been made in the previous year, was sent by Chairman Paul E. Gray to all donors of memorial gifts, members of the Class of 1942 and to all women recently widowed. All widows received President Vest's annual fund solicitation letter, and a newly published Life Income Fund brochure was sent to 1,200 selected widows.

Sustaining Fellows and Special Events Program

Under the management of Cassandra Page, the office of Sustaining Fellows and Special Events coordinated events at MIT and off campus. Among these were the dedication of the Muckley Building (E40), the CDC annual meeting, donor luncheons and a dinner honoring Professor Robert Mann. This office also assisted in the arrangements for the Emma Rogers Society meetings, the Dean's Breakfast Series for the Sloan School and the Faculty Fellows luncheon. In October, Sustaining Fellows brochures and membership lists were mailed to the entire membership of more than 1,100 people. In February, each Sustaining Fellow received a copy of the *Journal of the Institute for Hacks, Tomfoolery and Pranks at MIT*, accompanied by a letter from the Chairman of the Corporation.

Campus Visit Program

The Campus Visit office, managed by Estelle Cashman, organized six campus visits for 201 alumni, spouses and friends of MIT. Each visit began with an opening reception and dinner, followed by a full day of informational programs and dinner hosted by Dr. and Mrs. Vest at the President's House. The visits ended with a wrap-up breakfast at the Cambridge Center Marriott. Moderators included the provost, the vice president for research, the dean and associate dean of the School of Engineering, and the deans of the School of Science and the Graduate School.

Since the Campus Visit program began in October 1986, 629 MIT alumni and friends (usually with spouses or guests) have attended 36 visits. Over $45 million in commitments had been received from these campus visitors in response to solicitations made after their attendance. Two hundred and thirty-four faculty presented or participated in 210 programs during the course of the visits, and approximately 720 students have participated in the programs and/or joined the visitors for meals.

OFFICE OF CAMPAIGN SYSTEMS

As the research, production, and information systems complement to the National Campaign Office, the office of Campaign Systems supported this year's intensive cultivation and solicitation efforts. The level of information requests remained consistent with previous years (about 1100 requests for research backup; about 545 for ad hoc computer reports), as did the form of requests-backup for events or for solicitation and cultivation activity. However, because so much of the research and systems groundwork had been laid earlier in the Campaign, the office was able to juggle its usual activity with post-Campaign planning and initiatives.

Shelley Brown, the director of Campaign Systems, emphasized prospect identification efforts, training, and business needs analyses as the critical initiatives during the year. She is chairing newly created efforts for Resource Development and, separately, the ADDS Operation Group to develop a long term strategy for technology and information management. The office initiated a new Resource Development training program for career development, whose inaugural sessions this spring were on events planning.

Some of the initiatives included within the Campaign Systems groups were:

•The research staff managed a variety of projects aimed at identifying new prospects for the Institute. By monitoring news of public offerings, mergers and acquisitions, philanthropic activity and corporate affiliations, the staff surfaced 200 prospective individual donors to the Institute. Considerable effort was spent screening international alumni/ae and exploring new sources of information about them. Several new in-house databases were created as research tools, including one tracking funding opportunities within the Institute and another documenting Campaign events. The staff continued to maintain a database of alumni/ae founders, to issue monthly reports on alumni/ae corporate changes, and to track alumni/ae eligible for a Corporate Leadership Award.

•The programming group (Development Information Management Services) was involved in ongoing efforts to improve the efficiency of those files within the ADDS database managed by Resource Development. The group has also turned its attention to the reporting needs after the Campaign, and has created a process for identifying, prioritizing and monitoring all program and system changes.

•In the area of Macintosh production and systems support, the office developed a four-year plan for equipment upgrades and acquisition. The first phase of the four-year plan, to convert all of Resource Development to the Macintosh and to connect all users to the MITnet, will be completed by September 1992. The staff scheduled regular training/user meetings and created a newsletter on Macintosh developments and usage suggestions.

There were several personnel changes during the year. Mary Gulino, Assistant Director, retired after ten years of service to the Institute. Her responsibilities were divided between Lisa Donovan, who was promoted from administrative assistant to Coordinator of Production and Systems Support, and Diane Calabro-Bosco, who was promoted to Administrative Manager. Charles Carr, Senior Research Analyst, resigned to attend graduate school. Stephanie Grepo was promoted from support staff into his position, but transferred in the spring to assume a fundraising role with the Alumni Association staff.

FOUNDATION RELATIONS AND DEVELOPMENT SERVICES

Barbara G. Stowe, Director of Foundation Relations and Development Services, continued to develop and expand relations with private foundations. She also devoted considerable effort toward building the MIT alumni/ae base in Europe. Development Services, supporting the fundraising activities of the Schools and the Provost, is supervised on a day-to-day basis by John S. Wilson, Associate Director of Foundation Relations and Development Services.

Foundation Relations

Gifts from private foundations continued to make a significant contribution to MIT's educational and research programs. The foundation group's $155 million goal for the Campaign was reached early in the year and ultimately contributed $176 million to the overall effort. Foundation gifts this fiscal year totaled $22 million. Lisa Hiley and Susannah Abbott, Assistant Directors of Foundation Relations, left MIT to pursue other careers, having made important contributions to the program's success in recent years.

Development Services

The Office of Development Services, supervised by John S. Wilson, continued to pursue its mission of facilitating school-based development activities in tandem with the school development officers, faculty and the Office of the Provost. These included project management, the development of solicitation and cultivation strategies and stewardship programs. The demands on the office increased to a new high of 324 fulfilled requests for information on potential corporate, foundation and individual donors, which is more than a 60% increase over last year's productivity. Dr. Wilson has been providing key support for MIT's emerging K-12 initiative, which represents a new and innovative dimension in MIT's mission.

The staff's support of various school initiatives during fiscal year 1992 was vital to the funding of key projects within each of the schools. Within the School of Engineering, significant efforts were directed toward increasing the level of faculty activity in cultivation, solicitation and stewardship of individuals, as well as supporting such projects as the Hottel Chair, the Rohsenow Laboratory, the Rohsenow Fellowship, and the Apollo Program Chair.

The School of Science sponsored a number of informational events for alumni, the MIT community, and the public at large, including the Department of Biology's role in the Technology Day Program. The first steps were undertaken toward mounting a sizable endowment campaign focused on the Department of Earth, Atmospheric and Planetary Sciences, and work continued on identifying additional prospects for the new Biology Building, the Chemistry Outreach Program, and general needs of the Physics Department. The recent addition of a new Assistant Director for the School of Science, Laura Scarlett, enhanced the office's ability to meet the growing needs of the school.

A major Sloan School initiative was the Minority Fellowships program, which this year doubled the number of fellowships awarded. The program has a three-year goal of raising funds to meet at least half the tuition expenses of all Sloan minority graduate students and increasing their representation to 10% of the total Sloan graduate student population. Efforts continued to further develop the Business Associates program and the Center for Entrepreneurship.

The School of Humanities and Social Sciences focused on funding for the new Chinese Language Program, the Center for International Studies, and additional endowed chairs for the Economics Department.

The School of Architecture and Planning carried on an active schedule of cultivation and solicitation activities for key prospects. Also, fundraising continued for Rotch Library, as did work on identifying and researching new prospects for Architecture, Urban Studies and Planning, the Community Fellows Program, and the Center for Real Estate.

Development Services also provided support for a variety of initiatives for Provost Mark Wrighton, including the MacVicar Faculty Fellows Program and the Council on Global Environment. The office also works with the MIT Libraries to help expand their base of support, fund key projects, and build their endowment.

Throughout the year, Development Services expanded its stewardship role by centralizing responsibility for reporting on individual named funds. In addition to maintaining the stewardship system for professorships and scholarships, new cooperative efforts fostered with the Graduate School and the Alumni/ae Association were developed to improve donor relations with supporters of fellowships and with the reunion classes.

CORPORATE RELATIONS AND INDUSTRIAL LIAISON PROGRAM (ILP)

Corporate Relations, under the direction of Eric Johnson, continued to work at building mutually beneficial relationships with corporations worldwide. Most of the staff efforts have

been directed at developing and maintaining corporate participation in the Industrial Liaison Program and in developing major corporate gift support for the Institute.

In addition, special efforts were made during the year to support major activities in several departments and schools; strong involvement in the development of a long range strategic plan in the Aeronautics and Astronautics Department; support for the East Asian Initiative in the Sloan School of Management; fundraising support for the Joint Program in Global Change Science; significant assistance in developing additional partners for the Leaders for Manufacturing Program; as well as other programmatic initiatives. Beyond the Industrial Liaison Program fees and major corporate gifts, Corporate Relations also played a significant role in over $3 million in new research contracts.

The ILP, headed by Thomas Moebus, ended the year with 235 member companies, and revenues of $7.8 million. This represented a decline from the previous year, due largely to the effects of the poor economy and timing of fee payments, which included a larger than average amount paid early in the previous year, and a significant sum as yet unpaid during the current recession year. A newly created Corporate Advisory Panel , representing a broad spectrum of U. S. member companies, met twice during the year, and will meet at least once more. The Panel's mission is to learn from corporations how the ILP can better serve their interests and objectives, and to share information on how MIT and industry can work better together.

Corporate Development, directed by Karl Koster, reported corporate cash gifts during the year of $31.7 million, down from the record setting pace of the previous year. Like the ILP, corporate gifts were affected by the recession, as well as the absence of major programmatic initiatives which produced significant commitments in the previous year. Toward the end of the fiscal year, several major pledges were received from new and existing partners in the Leaders for Manufacturing Program. Despite the recent decline in cash receipts, Corporate Development ended the *Campaign for the future* with $236.7 million in commitments, 105% of its goal.

Promotions in Corporate Relations included the following: Wendy Elliott to Senior Liaison Officer; K. C. Klingensmith to Editorial Information Coordinator; and David Lampe to Associate Director of the ILP. New appointments included Robert Brandt and John Sherwood to Industrial Liaison Officer. Beni Inouye retired in July 1991, and Sandy Yulke took a leave of absence to attend graduate school. Eric Johnson, who has served MIT for twenty years, is also leaving to become vice president at Carnegie Mellon University.

National Business Committee

Robert Hagopian, Director, continued to divide his time between National Business Committee and *Campaign for the future* activities. Increasing emphasis was given to the solicitation of North American companies for ILP membership, coordinating closely with the ILP's marketing efforts. Twenty companies in the U.S., Canada and Europe were contacted during the year, and progress was made in cultivating Canadian corporations for the provision of scholarship support for Canadian students. In addition to directing Campaign activities in Canada and Seattle, diverse assistance was provided to school development officers and district directors responsible for other areas, including Boston and New York. With Barbara G. Stowe, several meetings were arranged with alumni capable of identifying key prospects in Europe.

Other activities included overseeing the process of evaluating alumni for the Corporate Leadership Award, and providing liaison between Resource Development and the Alumni/ae Association in the selection of alumni for awards, committees and offices. These responsibilities are increasingly important in building a strong alumni base and in the cultivation and recognition of alumni.

COMMUNICATIONS

The Office of Communications, directed by Elizabeth T. Harding, is responsible for the coordination, production, and distribution of all Resource Development publications. A number of the publications created in the past year have been related to the *Campaign for the future* putting forward accomplishments and priorities and aiding in stewardship and donor recognition. *Spectrum,* a 16-page newspaper started in 1987, published four issues during the year; post-campaign it will continue, but be reduced to three issues. The Corporation Development Committee newsletter for volunteers, *Campaign Reports,* came out twice and will likely be succeeded next year by another publication that supports alumni/ae activities, volunteers and the CDC. Another cooperative venture with the Alumni Office continued with the publication of four issues of *Parents News.*

Following a "Traveler's Briefing" by MIT faculty and administration for Resource Development staff, the office created a number of one-page briefs to provide background information for the fundraising field staff and volunteers. The topics included the Biology Building, financial aid, admissions trends and indirect costs. The staff assisted in the production of several new brochures to aid in fundraising efforts for centers and departments; three were completed on research programs and educational opportunities in the Department of Earth, Atmospheric and Planetary Sciences, the World Economy Laboratory, and the Center for International Studies. A pamphlet presenting an overview of environmental programs at the Institute will be completed by September 1992.

Communications continued the donor profile series of planned giving testimonials for *Technology Review,* and once again produced *MIT Facts,* a 44-page booklet presenting a brief, general overview of the Institute.

Glenn P. Strehle

ASSOCIATION OF MIT ALUMNI AND ALUMNAE

The final year of the *Campaign for the future* was by all measures a great success for the Campaign and for the Association of Alumni and Alumnae. Association President Peter M. Saint Germain '48 exercised his calm and focused leadership, concentrating his efforts on the successful conclusion of the Campaign. The Association's Alumni/ae Fund had a record year, besting last year's effort by $2 million, for a total of $17.1 million. President and Mrs. Charles M. Vest (Rebecca) -- Chuck and Becky as they have become known to alumni, faculty, staff, and students alike -- travelled widely for the Association, seeing alumni in several American and Asian cities. The Vests continued to open their home to alumni, parents, and students under Association sponsorship. The key to the Association's great success continues to be the increasing inclusion of alumni in more and more aspects of Institute life.

Over 3,000 alumni are involved in the efforts of MIT ProNet, the job search service provided by the Association. Work with secondary schools through volunteer alumni outreach grows, as does the Alumni/ae Travel Program. The close of the Campaign will enable the Association to expand thoughtfully its added service to alumni on a pay-as-it-goes basis.

This year was one of continued and heightened assaults on the university and the long-standing federal-university compact. President Vest has requested and obtained alumni support about these matters and the year closed with an unprecedented anti-trust suit in federal court over the methods MIT has used to award our scholarship funds. The outpouring of financial support as measured by the success of the Alumni/ae Fund is in no small measure an affirmation by alumni of support for MIT. Volunteer leadership, headed by Association President Saint Germain, was supported by an able Board of Directors and a strong Alumni/ae Fund Chair, Karen Mathiasen GM '71. Finally, volunteer support for the MIT Enterprise Forum has been restructured under the able leadership of R. Gary Schweikhardt GM '73. Each of these gifted and hard-working leaders represents one of the 4,900 volunteers who, with the Association's most dedicated staff, enable the Association to do so much for both MIT and its alumni.

ALUMNI/AE ACTIVITIES

In this final year of MIT's *Campaign for the future*, under the distinguished leadership of Association President Saint Germain and Fund Board Chair Mathiasen, the Fund set a new record of $17.1 million in gifts from 28,030 alumni and alumnae. The dollar total represents a new million dollar plateau for the Fund, exceeding last year's total by $2 million and exceeding by $900,000 the prior record set in FY '90, the Koch Challenge year.

This year, the Fund Board placed special emphasis on gifts designated to Project 2000, MIT's classroom renovation program. For gifts of $500 or greater designated for this purpose, donors received a "piece of the steps", a piece of limestone cut from the original steps of 77 Massachusetts Avenue. Nearly 600 graduates received mementos and some 1,200 alumni and alumnae contributed $640,000 in support of Project 2000.

Over the lifetime of the *Campaign*, the number of alumni giving to the Fund has doubled. Moreover, 48% of the donors this year made a contribution of $100 or greater, and the median gift from undergraduate alumni was $100, meeting a key *Campaign* objective.

Of the $710 million *Campaign* total, $105.2 million was credited to the Fund in cash receipts with an additional $13.5 million recorded in pledges. This sum represents 40% of the *Campaign* gifts received from individuals. More than 40,000 alumni, 55% of the active alumni participation, contributed to the *Campaign for the future.*

While taking pride in the remarkable totals cited above, it is important to note that the past two years have been difficult economic years and it has taken extraordinary efforts by several thousand

alumni and alumnae volunteers to encourage their fellow graduates to increase the amount of their annual support of MIT in order to achieve these outstanding gift results.

This year marked the first in which every reunion class, from the 5th to the 70th, presented Dr. Vest with a class gift. Moreover, regional volunteers lent their support through participation in the Telethon and Alumni/ae Fund Visit Programs (AFVP). Graduate alumni and students, aided by faculty and staff, made calls seeking support for academic departments.

Beyond these direct efforts in support of the *Campaign* and the Fund, alumni leaders of regional clubs, special constituencies, and class officers organized hundreds of meetings featuring faculty members, senior Institute officers, and other notables. These and other alumni activities are detailed in the following paragraphs.

ALUMNI/AE FUND VISIT PROGRAM (AFVP)

The AFVP completed its mission as a separate program under the Activities unit of the Association effective with the end of the *Campaign*. This successful program will continue under the aegis of the five regional directors, the Reunion Gift staff, and Graduate Alumni Programs. Over the life of the five-year *Campaign*, there were 73 individual visit programs organized, involving 588 volunteer solicitors resulting in $4.6 million in gifts received from over 1,900 alumni.

During FY '92 alone, 19 programs were organized throughout the United States in which 176 volunteer alumni and alumnae solicitors contacted 382 prospects raising in excess of $1 million, inclusive of corporate matching gifts. Many of these gifts included five year pledges and most alumni doubled the size of their prior gifts to the Fund.

Over the five-year course of the *Campaign*, a new cadre of nearly 600 alumni/ae were recruited and trained in face-to-face solicitation techniques, with just under 200 coming from the two youngest decades of alumni.

TELETHON PROGRAM

Nearly 1,000 volunteers, including alumni, students, faculty and staff, contributed to the success of this year's telethon program. Pledges in excess of $754,000 were received from nearly 70% of the alumni and alumnae contacted this year. Approximately 23% of the active alumni/ae body, over 16,200 graduates, were reached during telethons held on campus and in 19 cities throughout the United States. Gifts from telethon pledges represented one-third of the contributors credited to the 1992 Alumni/ae Fund.

During FY '92, the regional directors recruited 199 callers in 16 cities who contacted over 3,300 alumni and raised $252,000. Telethons continue to be one of the best fund-raising techniques available, and MIT stands in the top rank of universities in terms of the number of alumni volunteers participating as callers.

REGIONAL PROGRAMS

With over 72 clubs worldwide, local MIT club programs continue to provide alumni/ae with meaningful venues to stay in touch with MIT and each other. This year, many clubs had unprecedented numbers of meetings, with the Club of Northern California topping the list with 81 meetings in FY '92.

Some highlights were visits to clubs in Philadelphia, Texas, Chicago, Minnesota and Florida by President Vest; talks by professors from the Laboratory for Environmental Health Sciences; and the initiation of an Ad Hoc Committee of alumni and staff to determine what factors contribute to a "model club" and how MIT clubs can continue to attract and retain members in a changing society.

CLASS PROGRAMS

Class reunions are the focal point for MIT class program activity. During 1991-92, 175 volunteers worked with staff to plan reunion activities which included receptions, dinner dances, cruises, disco parties, and seminars. Over 1,600 alumni, alumnae and their guests attended reunions June 4-6. The most senior reunion class, the Class of 1922 celebrating its 70th reunion, was represented by a group of seven graduates and their eight guests. The Class of 1942 set 50th reunion attendance records with 290 people participating in their reunion program. The classes of 1956 and 1946 held fall reunions in autumn, 1991, instead of the usual June reunion.

Reunion gifts and pledges of nearly $32 million were announced from each of the fourteen reunion classes on Friday, June 5 at the Technology Day luncheon. The Class of 1942's gift of $10.1 million broke a 19-year record for a 50th year class; it also sets the record for the largest reunion gift in MIT history. Close behind, the $9 million gift of the Class of 1927 also broke records.

Four classes presented premier reunion gifts: the first 70th reunion gift from the Class of 1922, $2.3 million; the first 55th reunion gift from the Class of 1937, $576,000; the first 45th reunion gift from the Class of 1947, $571,200; and the first 20th reunion gift from the Class of 1972, $178,000.

Other reunion gifts included $3.3 million from the 40th reunion Class of 1952, of which $186,000 was earmarked for the "Class of 1952 Educational Initiatives Fund," the class project supporting MIT's K-12 initiatives; $1.7 million from the 25th reunion Class of 1967, of which $166,000 was designated to the Kenneth Wadleigh Scholarship Fund; and $2.4 million from the Class of 1932; $591,000 from the Class of 1957; $2.6 million from the Class of 1962; $112,450 from the Class of 1977; $56,000 from the Class of 1982; and $24,150 from the Class of 1987. At Commencement on June 1, 1992, the newest alumni class of 1992 presented gifts and pledges of $27,800 for the Program for the Encouragement of Technology.

Class giving campaigns in non-reunion classes were conducted by 70 class agents who acknowledged many of the 18,698 gifts made to the Alumni/ae Fund by undergraduate alumni and sent their annual letters encouraging class members to participate in the Fund. Anticipating their upcoming 50th Reunion, the Class of 1944 gift of $403,887 was the largest non-reunion class gift in the Alumni/ae Fund; the Class of 1935 had the highest non-reunion class participation with 59% of its members making gifts in the 1992 Fund; 51% of all undergraduate alumni donors made gifts equal to or greater than $100.

Key to the continuing success of class programs is the program of activities conducted with undergraduate students. This year, the first full year of activity for the Student Alumni/ae Council (SAC), saw an increase in student/alumni involvement. A student telethon volunteer committee helped recruit 450 student callers for the best student telethon in recent years. Thirty-five student ambassadors assisted alumni/ae during Alumni/ae Week and ran the Progeny Program for alumni offspring; 403 seniors and 62 alumni participated in Senior Dinners, hosted by President and Mrs. Vest at the President's House; and 1,400 students enjoyed the finals lounge sponsored by the Association in the Bush Room.

The Association continues to emphasize recent alumni involvement. A reassignment of staff responsibility for young alumni has emphasized regional club programming for recent alumni and has associated support for the most recently graduated classes with the staff who supported them as student volunteers. The Association welcomes new graduates by sending a publication called *Passport to MIT, the World at Your Doorstep*, which describes the benefits to and responsibilities of alumni. An annual student/recent graduate volunteer recognition barbecue attracted over 100 people this spring. A travel subsidy for recent alumni volunteers supports their participation in the Alumni/ae Leadership Conference, resulting in greater participation of young alumni in the 1991 conference. More than 60% of undergraduate alumni make at least one gift to MIT by the fifth reunion, one measure of the success of our emphasis on this important alumni/ae constituency.

ALUMNI/AE WEEK AND TECHNOLOGY DAY

In addition to providing support for class activities, from June 3-7, 1992, the Association sponsored a full program of Alumni/ae Week activities for nearly 2,700 returning alumni and guests. General alumni

programming included Tech Night at the Pops (attended by 2,000 MIT supporters), the Memorial Service in the MIT chapel, the annual Technology Day Program and luncheon, the Techsas Barbecue and Alumni/ae Challenge Games on Saturday (won by the 25th Reunion Class of 1967), a young alumni party on Saturday evening, and special activities for the Cardinal & Gray Society, composed of alumni who have observed their 50th Reunion. The weekend also included reunion activities for the Sloan School, the 75th anniversary of Course VI-A, and CAES alumni. General alumni participation continues to grow along with the growth of reunion class participation. This year general alumni participation exceeded 35% of all Alumni/ae Week participants. Beginning with the Class of 1918, every class but two (1919 and 1929) had a representative attending Alumni/ae Week activities.

The Technology Day program, "Winds of Change: Achieving Global Business Excellence for America in the 21st Century," was organized under the guidance of the Technology Day Committee, chaired by Kenan Sahin '63. The popular topic was presented in a morning symposium and afternoon workshops conducted by 27 MIT faculty and alumni speakers. The program was conceived with guidance from Deans Lester Thurow HM, Joel Moses MA '67, and Philip Khoury, and Professor Donald Lessard. The morning symposium was led by Professor Lessard, Professor of Management. Professor Suzanne Berger, Ford International Professor of Political Science and Head of the Department of Political Science, was the keynote speaker. Her presentation was followed by remarks from Professor Sumantra Ghoshal GM '85, Associate Professor of Management at the European Institute of Business Administration; Paul E. Gray '54, Chairman of the MIT Corporation; Dean Moses, Dean of the School of Engineering; and Professor Richard Schmalensee '65, Gordon Y. Billard Professor of Economics and Management, MIT Sloan School of Management.

ALUMNI/AE LEADERSHIP CONFERENCE

The 1991 Alumni/ae Leadership Conference, held on Saturday, September 21, was attended by over 400 alumni/ae leaders and their guests. Following the annual meeting of the Association, Association President Saint Germain introduced President Vest, who spoke about issues facing MIT for the coming decade and conducted a question and answer period with the volunteers present.

The program for the afternoon gave alumni volunteers the opportunity to hear from members of the new MIT administration and featured a panel led by Provost Mark S. Wrighton whose members were Dean Robert Birgeneau, School of Science; Dean Khoury, School of Humanities and Social Sciences; and Dean Moses, all recently appointed to their positions. The panel topic was "Research and Education in the 1990s."

Association President Saint Germain presided over the annual awards luncheon, at which 22 alumni and alumnae were recognized for their outstanding service to the Institute.

This conference, revived in 1989 after a brief hiatus, serves as MIT's primary opportunity for recognizing and training volunteers. In addition to the Saturday program, over 200 volunteers attended preconference workshops on Friday, September 20, for class officers, club officers, Educational Councillors, and others. Of those attending the conference, more than 30% had graduated since 1980, evidence of the success of special efforts to involve young alumni.

GRADUATE ALUMNI/AE PROGRAM (GAP)

In order to establish a comprehensive program for graduate alumni an ad hoc committee took on the task of addressing the following four questions: what activities and programs will appeal to graduate alumni; what types of volunteer involvement opportunities and level of opportunities should the Association strive for with its graduate alumni; how well is the Association communicating with its graduate alumni; post-campaign, what modes of fund-raising should be considered. After a year of small group discussions, information gathering, and data analysis a post-campaign strategic plan was compiled.

Key recommendations include annual partnership events with departments, increasing the percentage of graduate alumni giving at the $100 level while steadily growing the base of graduate donors.

Particular relational events will continue to be designed to complement current Association programs such as the Alumni/ae Leadership Conference, Technology Day, and regional events. There are also new efforts held in conjunction with professional associations around the country. In order to provide this increased activity the GAP staff has been increased from three to five.

Fund-raising results from graduate alumni resulted in $3,190,106 and 9,332 donors in the 1992 Alumni/ae Fund, representing 33% of the donors and 18% of the overall annual fund dollars.

PARENTS PROGRAM

The third MIT Family Weekend was attended by 1,900 parents and students, an increase of nearly 10% over the previous year. The Parents Fund, also growing in its third year, received 240 gifts from non-alumni parent donors, and reported gifts of $640,500 from all MIT parents. The program newsletter, *Parents News*, was sent three times this year to the 5,000 families on the Association's database. A special summer edition was sent to parents of incoming freshmen. The program, conducted in collaboration with the Office of the Dean of Students Affairs and the Office of Resource Development, is managed by Association staff.

SPECIAL PROGRAMS

Association of MIT Alumnae (AMITA)

New initiatives by AMITA this year were the Women's Athletic Day in May and an evening with Associate Provost for the Arts Ellen Harris and the MIT Symphony Concert, co-sponsored by the MIT Club of Boston. In addition, the total of the Margaret MacVicar '65 AMITA/UROP Oral History Project increased to $50,000 toward the endowment goal of $100,000. These funds have allowed women undergraduates to elicit, transcribe and analyze interviews with Elizabeth Drake '58, Emily Wick CM '51, Marjorie Pierce '22, Bertha Dodge '22, Martha Munzer '22 and Leona Zarsky '41.

Black Alumni/ae of MIT (BAMIT)

BAMIT organized a highly successful 12th Annual Meeting in October in collaboration with the MIT Enterprise Forum, attracting nearly 100 conferees; sponsored an exit reception for graduating minority seniors; and hosted a reception and luncheon for black alumni during the 1992 Alumni/ae Week. BAMIT also initiated discussions with the Association to explore ways of celebrating the 100th anniversary of the first known black graduate of MIT, Robert R. Taylor SB 1892 in Architecture. BAMIT continued its fund-raising campaign to endow the Ronald E. McNair Scholarship Endowment Fund. Currently, the Fund total stands at $83,000 towards the goal of $150,000.

Boston Seminar Series

This year's Boston Seminar Series consisted of six lectures from November 1991 to April 1992. Speakers and topics were: Frederick P. Salvucci '61, Senior Lecturer at the MIT Center for Transportation Studies, former secretary of transportation and construction of the Commonwealth of Massachusetts, "Transportation"; Professor Robert A. Weinberg '64, Professor of Biology, MIT, "The Social Perspective on Biotechnology"; John H. Rich, Jr., Veteran NBC News Foreign Correspondent, Peabody Award Winner, "War and Reporting"; Professor Joan Rothschild, Professor of Political Science, University of Lowell, "Women, Technology, and Society"; Paul Levy '72, executive director of the Massachusetts Water Resource Authority, "The Environmental Perspective"; and Professor Arthur Miller, Bruce Bromley Professor of Law, Harvard Law School, "The Rights to Privacy." The seminar series committee was chaired by Robert Asher '78. Alumni subscribers to the series reached 130.

ALUMNI/AE ACTIVITIES STAFF

Staff changes during the year included the promotion of Kristin L. Montemagno, to Coordinator, Alumni/ae Fund. New staff members include Stephanie L. Grepo, coordinator for GAP; William W. Redway, Jr., program manager, GAP; Maryglenn Vincens, program director, student and parents programs; and

Annette E. Williams, coordinator, parents program. The following individuals resigned: Susan L. Anderson, area director, AFVP; Leslie Wolff Borak, area director, AFVP; Cathy Hatfield Brown, coordinator, major reunion giving; Lore A. Greene, coordinator, GAP; and Jodi Rafus, coordinator, Alumni/ae Fund. Laura M. Scarlett left the Association staff to accept a new position in the Office of Resource Development.

In the final year of the *Campaign*, staff continued to improve their level of support to volunteers. Of special note is the effort taken to engage more staff to support reunions and Technology Day, the single biggest annual event bringing several thousand alumni back to the campus. This year's events, outlined above and enjoyed by all, presented a significant challenge to the staff, who were equal to the task.

ASSOCIATION OF ALUMNI AND ALUMNAE AWARDS

Bronze Beaver Awards
Bradford Bates '59; Bonny Kellermann '72; James Levitan '45; Karen Mathisen GM '71; DuWayne Peterson '55; Wendyl Reis, Jr. '56.

Harold E. Lobdell '17 Distinguished Service Awards
Albert M. Bottoms MT '62; John Brown '32; John Jarvé, Jr. '78; William L. Maini '51; Allan Q. Mowatt '35; Miton H. Roye, Jr. '78; Philip R. Sayre '54; Edward T. Thompson '49.

George B. Morgan '20 Award
George Butzow '51; Michael Goldman '52; Raymond Laub '60; John Morefield '56; James Neighbours AA '41.

Henry B. Kane '24 Award
William Brody '65; Ernest Cohen '64; Stanley M. Rose '67.

Presidential Citation Award
Class of 1950 Student Financial Aid Fund; MIT Club of Cape Cod; Young Alumni/ae Steering Committee of Boston; MIT Club of South Texas; MIT Club of Boston; Productivity Commission Road Show

Honorary Membership
Dean Lester Thurow; Professor Franco Modigliani

TECHNOLOGY REVIEW
Former managing editor Steven J. Marcus returned to *Technology Review* as its new editor-in-chief. Mr. Marcus has brought energy and insight to his new role and has continued to improve the magazine. Philip LoPiccolo also replaced long-time senior editor Marc Miller '59. *Technology Review* received two second-place awards from the Society of National Assocation Publications, one for general excellence and one for feature writing.

Despite the worst year in the history of the advertising industry, *Technology Review* maintained its budget by reducing expenses to offset the advertising shortfall. Outside circulation remained stable, with the cost of acquiring new subscribers low. The business staff has been surveying several hundred readers after each issue for their reactions to specific articles, and the response has been overwhelmingly favorable.

The startup of the French edition of *Technology Review* was postponed because of the poor advertising climate in Europe, but the organizers expect to revive the project when the economy improves. The New York Times Syndicate continues to distribute *Technology Review* articles to US newspapers and magazines abroad for excerpt.

The magazine made a difficult but successful move to desktop publishing, with the production staff taking over many of the functions previously performed by the printer. The redesign of the MIT section and switch to higher quality paper was postponed because of the difficult budgetary year.

ALUMNI/AE INFORMATION MANAGEMENT

Fiscal Year 1992 was a cost-saving year. Two major project undertaken were reduction of the mainframe computer expenditure and conversion of ZIP codes in the database to the new ZIP code + four format.

Mainframe computer expenditures were reduced by 20% while computer usage increased. The major reason for the reduction was an on-line program code generator that is able to write the Natural program code for on-line users in a more efficient way.

The ZIP code + four conversion had been ongoing for over a year. According to US Postal Service standards, the Association's active database of addresses is now 85% converted to the new format. The Association and other MIT departments using Association files for mailing labels should see a reduction in their mailing costs.

Two ongoing minor projects begun in FY '92 are to find lost alumni and to find companies with matching gift programs. Two thousand of the total 12,000 missing alumni have been located to date. The on-line matching gift process has been modified to update company file information automatically if a company is part of the matching gift program.

ADMINISTRATIVE SERVICES

The administrative unit continued to carry out its fiscal, personnel, and service responsibilities with efficiency and aplomb. The Alumni/ae Travel Program continued to do well, and seeks to expand the involvement of MIT faculty in its trips. Several successful events with travellers and local alumni/ae clubs have taken place, including a gathering in Istanbul. Macintosh operations also continue to burgeon, with much of *Technology Review* being produced through desktop publishing on Macintoshes; an ever-widening communication network using QuickMail; and the prospect of network fax and other informational innovations. Katherine R. Cochrane, Director of Finance and Administration, is taking an active role in the decision-making process regarding changing needs of the New York Alumni Center, working with a subcommittee of the Association Board of Directors.

WILLIAM J. HECHT '61