
Massachusetts Institute of Technology

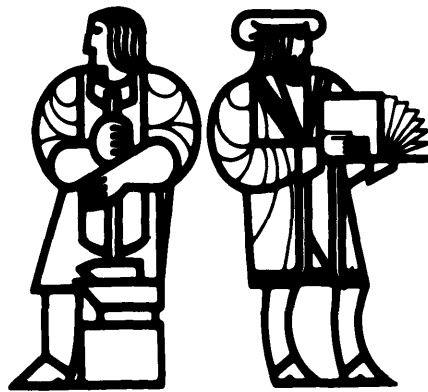
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Reports to the President

1988-89

Massachusetts Institute of Technology



Reports to the President

1988-89

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1988-89

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PRESIDENT

A great university, like the society of which it is a part, is continually molded by the struggle of contrasting forces. It is the ancient idea of opposites in dynamic balance.

This year, I have been particularly conscious of that struggle within MIT, as we try to preserve what is best about this institution while at the same time renewing and transforming it for a new century.

I have also been conscious of the interplay of forces beyond our own walls this year — a year during which the candidates for the Presidency of the United States seemed determined to concentrate on secondary issues; when a series of Congressional hearings brought the very nature of scientific inquiry into question, and in which we witnessed the horror of students massacred in Tienanmen Square.

There were also continuing reminders this year that scientific literacy in the United States is at a low ebb. Not only do most Americans understand very little about scientific issues, they have come to distrust scientists, perhaps out of helpless anger that we have such disasters as pollution of the atmosphere, oil slicks on the seas, and hazardous wastes dumped under the earth.

All this affects us deeply here at MIT, because a science-based university is no ivory tower. For better or worse, we are in the thick of the battle.

But this raises a problem. We welcome spirited debate; it is essential to the kind of institution and society in which we want to spend our lives. Yet for an institution, or a nation, to withstand the forces that continually pull it apart, there must be a center that holds — a sense of common cause that is broadly and deeply felt.

What is the nature of that “center” at MIT?

Certainly it includes our focus on science and technology. Certainly our refusal to equivocate about excellence is part of it. Certainly it includes our attention to the education of our students, our pursuit of research that pushes back boundaries, our respect for individual achievement, and our embracing of individual differences in background and belief that make this such a special place.

But I believe that a sense of partnership, of shared vision, and of shared mission in serving the needs of society is part of our center too. And I believe that sense needs to be strengthened and reaffirmed. In this year’s report to the Corporation, I want to explore the need and the opportunities for partnership and common vision, both within MIT and among the institutions of society.

Common Cause Within MIT

The most central issues we continue to debate within MIT concern our curriculum: whom should we be educating, what should we be teaching, and how should those issues be decided. I am happy to report that we have made significant progress on all these questions this year.

First, whom should we be teaching?

Until quite recently, the majority of Americans were of European ancestry, as were most students applying to American colleges and universities. Until quite recently, the majority of students enrolling in the research universities were white and male. And until quite recently, the majority of students going to college had had adequate preparation in secondary school.

All of that is changing. America’s cultural focus is no longer concentrated on Europe. The barriers of race and sex are falling, however slowly. And many of our public schools are failing.

8 President

In the 1990s, it now seems clear, both commerce and the work force will change drastically in the United States. Economic growth is likely to be slower, continuing a trend that has been evident during the 1980s. Employers will need fewer workers. However, they will need workers who are better educated and more highly skilled, because the growth occupations will be in the technical, professional, administrative and managerial fields, and because the characteristics of jobs — essentially all jobs — will change at an accelerating pace.

Demographic data, however, show this is not the kind of labor force we are likely to have — unless we recognize changing circumstances and make the appropriate changes in our educational programs. The American work force is dramatically increasing in heterogeneity, as more people emigrate to the United States from Central and South America and the Far East. Already, fewer workers speak English as their primary language. More workers than ever before are women and minorities. More are parents — especially single parents — who must juggle the demands of child care and jobs. More are, and will be, supporting aging parents as well as children. And more will be failed by our public schools.

Public schools in the United States have become so unable to do their job, in fact, that some larger companies are trying to take up the slack themselves. Not only are they providing on-the-job training, they are providing remediation in basic skills so their workers can become trained. It is bitter irony that we have seen our effectiveness in public precollege education decline to the bottom rank of developed nations even as the growing internationalization of business demands better education and stronger skills.

What will all this mean to MIT? What effect might it have on our admissions policies, particularly as they bear on undergraduate education? What effect will it ultimately have on the quality of life here?

We draw our student body from the highest ranks of the secondary schools in the United States and abroad. But for some time now, there has been a sense among some members of the faculty that the performance of MIT students in science and mathematics is declining, and that high test scores do not count as strongly as they should, and once did, as admissions criteria.

Over the last year the Committee on Undergraduate Admissions and Financial Aid (CUAFA), working closely with the Admissions Office, conducted an intensive review of the Institute's admissions policies and procedures.

The committee compiled both quantitative and qualitative data, including in-depth interviews with faculty members and administrators, to see whether there have been discernible trends in student performance over time.

Because the quantitative data were not conclusive, the committee relied strongly on its discussions with faculty members, primarily those who have been teaching the same subjects over a long period of time.

About half the faculty interviewed expressed no major concerns about students' academic performance. The other half expressed varying degrees of concern, with the Mathematics Department expressing the most. But many faculty believe changes in students admitted to MIT reflect not so much a decline in students' academic ability as a broadening of their interests — beyond a strict focus on mathematics, science and engineering. One math professor described his current students as "just as bright [in math], but less interested than they were ten, or even five years ago."

With respect to admissions, the committee concluded that changes in the entering class at MIT over the last thirty or so years reflect not so much changes in the pool of students available (test scores of the class entering in 1962 were very similar to those of current classes), as changes in society. They also reflect the conscious change we have made in the kind of institution MIT is: a richer and more diverse place, with a larger proportion of women and people of non-European ancestry. In recent years, test scores in mathematics and science *have* been counting less than they used to in getting into MIT because more factors are now considered.

In making its recommendations, CUAFA believes that admissions decisions should place greater weight on demonstrated capabilities in MIT's traditional strengths, science and mathematics, regardless of the student's

ultimate field of study. It recommends that we continue our efforts to admit more women and minorities to the Institute; and that we continue to consider both numerical and non-numerical factors as criteria for admission.

The committee particularly believes that we must revitalize the linkages between the faculty and the admissions process at MIT, so that more faculty are informed about and involved in admissions.

The report of CUAFA was made in May, very near the end of the academic year. Although there was an opportunity at the final faculty meeting of the year for a first, brief discussion of the report, we will return to the discussion in the fall so as to give faculty an opportunity to engage these issues more fully.

I believe that CUAFA, under the energetic leadership of Professor Keith Stoltzenbach, has performed a great service to the Institute in its careful review of this very important subject. I know I speak for many members of the faculty, as well as for myself, in expressing our appreciation.

The views of CUAFA concerning gender and ethnic diversity within MIT's undergraduate population also have implications for the admission of graduate students, and for recruitment and development of faculty.

MIT is indeed a meritocracy; it is part of our heritage to reward the best. But that is not mutually exclusive with another objective: to weave what Margaret Mead called "a less arbitrary social fabric." Currently, MIT's undergraduate classes are approximately one-third female and one-eighth underrepresented minorities.

At the graduate level, about 20 percent of our students are women, and about eight percent are minorities. In contrast, about 10 percent of our faculty are women, and less than two percent are underrepresented minorities. With respect to minorities, better representation on the faculty is greatly hindered by the fact that the pools of minority Ph.D.'s in engineering and science are so small — less than one percent of the cohort — and that they have significantly decreased over the last decade, rather than increased.

Greater representation of minorities on the faculty of the Institute requires greater effectiveness in helping the ablest minority graduates to pursue doctoral-level education. In the past year, together with seven other research universities, we have undertaken a collaborative effort to develop a multi-institutional program that would provide support for underrepresented minorities through their postdoctoral years with the understanding that they would go on to pursue academic careers at one of the participating institutions. Currently, we are seeking financial support for this venture from a number of major foundations.

Obviously, such a program will take some time to bear fruit. In the meantime, it is important that we recognize the need for changes, not only in programs, but in attitudes, if we are to make real progress in achieving a pluralistic intellectual community here. I believe that one of the reasons we haven't made more progress is that so many of us at MIT have measured it in terms of our responsibility to help the underprivileged, to be compassionate, to create opportunities for those who have had less than we have. We have tended to see our equal opportunity programs as doing the right thing for someone else — as doing a favor to others by opening up our doors. No wonder we haven't made much progress. It hasn't occurred to many of us that we have something to gain, culturally and intellectually — and that is the vitality and richness that comes from incorporating and learning from differences. Instead of regarding our differences as stumbling blocks, we should see them as sources of complementary strengths — resources to be tapped for the common good.

* * *

What we should be teaching is an ongoing discussion at MIT. But since 1985, several groups of faculty have been engaged in the most thorough rethinking of the university's undergraduate curriculum in 25 years. Because it is so thorough, the full process of review and change will not be complete until sometime in the 1990s. Its objective is to ensure that our undergraduate educational programs are appropriate to the changing frontiers of science, engineering, and related fields; and that they reflect, as fully as possible, the lifelong educational needs of our graduates. The changes that result from this review will have a profound effect on the culture of the Institute.

10 President

In last year's report I discussed changes we have already made to the curriculum: to the General Institute Requirements with respect to the Humanities, Arts and Social Sciences; in the advising of first-year students and in development of interdisciplinary "context courses." This year, the focus has been on grading policy, on the science core subjects, and, within the School of Engineering, on professional programs.

The School of Engineering is exploring how best to achieve a balance in its offerings between depth of competence in one professional field and breadth of exposure to other fields, both within and outside engineering. One critical question being examined is whether any engineering school can realistically prepare students to practice engineering in only four years.

In the School of Engineering and throughout the Institute, much of the current debate is an attempt to grapple with ways to expose our students to many approaches to knowledge, and to encourage them to make connections and analogies among those approaches. We are exploring whether there ought to be a fundamental rebalancing of emphasis in an MIT education, with somewhat less emphasis on principles, analysis and research; and more on design, integration, synthesis, and implementation.

Many at MIT are convinced that the scientists and engineers of the future ought to have a broader understanding of the context in which they do their work — and beyond that, that our graduates should become better guardians of the workplace and of the environment. That means that we must open wider windows onto the world for our students. And because curriculum decisions made at MIT often become models for other institutions to follow, the decisions we are making about education here are likely to have far-reaching implications.

Implicit in this discussion of MIT's undergraduate curriculum is a strong concern about the scope of the education we have been providing our students for the last few decades.

In any higher civilization, there must be experts, and experts must be relied upon for advice. In our society, expert knowledge is usually deemed more necessary and worthy of reward than "liberal," or contextual, knowledge. Yet all of us have had experiences which illustrate that it can be dangerous to rely completely on experts who have achieved their understanding by limiting their fields of vision. In a world that will be increasingly interconnected, our aim must be to strengthen the connections between learning a specific field, and broader, more contextual learning. It will not be an easy task.

One of the most interesting — and challenging — undertakings to have emerged so far from this curriculum review has been the creation of "context courses" that are designed to explore how science and technology fit into the social order, and to encourage students to think about the intellectual, moral and social issues associated with scientific advancements. Nine new context subjects were presented during this past year, and 13 will be offered during the 1989-90 academic year.

Those faculty who are reviewing the first two years of context activities regard them as vital to the education of our undergraduates. It is clear, however, that a structured, required context experience would not be welcomed by the faculty at this time. Nonetheless, I believe it is desirable for students to have a range of interdisciplinary perspectives and offerings in a variety of forms, so that context-type experiences are embedded into the undergraduate degree program, and I am heartened by the continuing new developments in this area.

In the review of the science component of our core requirements, the faculty voted this past May to endorse the addition of a biology requirement to the core. Currently, our students are not required to study biology (although many do), and there is a broad-based desire among the faculty for all undergraduates to have a serious intellectual acquaintance with modern biology. The form the requirement might take is not yet set. In vintage MIT style, endorsement of pilot subjects to try out several forms was explicit in the faculty's vote. A two-term integrated chemistry-materials-biology sequence, team taught by three departments, already is underway this term.

The format of a biology science core requirement will be part of the restructuring of the Science General Institute Requirements that will be voted on by the faculty in about two years' time. It is virtually certain that an addition to the science core cannot take place without coming to terms with fundamental issues concerning the

current science distribution component, the physics component, and the quality of students' laboratory experience.

A review as comprehensive as the one we have undertaken cannot be accomplished without disagreement and tension, and we are experiencing both. But I believe it is a vitalizing and healthy kind of tension. People are deeply engaged in the debate, and they care very much how it all turns out.

At MIT any proposal for change that addresses the larger issues and goals of education is, and must be, done with the leadership and participation of the faculty, because it is the faculty who are responsible for determining who shall study here, what shall be studied, and how it shall be taught. Consensus-building in this process, as time consuming, nonlinear and messy as it may be, is at the core of what the Institute is about. Certainly without broad consensus, no effective action is possible.

So as difficult as it sometimes seems to engage such fundamental issues with small, incremental steps, that is the way we must proceed if the innovations we are considering are to become part of the culture of MIT — and ultimately, to affect the course of society at large.

Common Cause Among the Institutions of Society

These are not glory days in the United States for science and technology.

The "fusion confusion" of a few months ago is an example of what can happen when scientific integrity is overtaken by the drive for fame and fortune (institutional as well as personal), and when the public and the press are so ill informed about science. In the early spring, two chemists — one from Utah, the other from England — called a press conference to announce they had achieved a form of fusion at room temperature that produced more energy than it required, raising the hope once again that the world might have a cheap, limitless energy source.

The news was reported as though nirvana were at hand. And it was reported without the necessary detailed descriptions of the work, which might have encouraged critical assessment and efforts at duplication. Even now, several months later, other scientists have been unable to duplicate that result and the public is more skeptical of science and scientists than ever.

We have experienced other troublesome indicators of public misunderstanding of the purpose and process of science and technology. Twice since last spring, representatives of MIT have testified before Congressional subcommittees on matters of concern to the scientific and academic communities. Neither occasion was cause for confidence.

On the first occasion, several senior members of our faculty appeared before a subcommittee of the House Energy and Commerce Committee, the Subcommittee on Oversight and Investigation chaired by Representative John Dingell (D-Mich.). They were there to respond to allegations that research which underlay a paper written by MIT scientists and others and published three years ago in the scientific journal *Cell* was at best in error and at worse fraudulent.

Reviews of the matter conducted at MIT; at Tufts University, where one of the coauthors serves on the faculty; and by the National Institutes of Health, which sponsored the work, all concluded that while there were some errors in the research, as happens often in science, there was certainly no fraud or misrepresentation. Nonetheless — and incredibly — this time the Secret Service became involved, investigating researchers' notebooks.

In science, error is not a crime; it is a necessary part of the process — a process which is dispersed, interdependent, cumulative, and ultimately self-correcting. It is a process that not only fosters the rapid development of new knowledge, it enables researchers to consider new findings, make corrections for error, and verify the accuracy of results.

12 President

What was particularly disturbing about the Dingell hearings was that some members of Congress and the Congressional staff seemed unable to see any difference between intentional fraud and error. And, they suggested formal methods for reviewing research results that at best would be wasteful and unproductive, and at worst would inhibit scientific speculation and discourage research that challenges conventional wisdom or approaches.

The potential for damage to science from the attitudes represented at these hearings is very disturbing. Without better understanding of science and its methods, public support of scientific research is in question — and the specter of governmental policing of science raises its head.

The second time a member of the MIT community appeared before a Congressional subcommittee in recent months was in June, when I testified before the Subcommittee on Human Resources and Intergovernmental Operations of the House Committee on Government Operations, chaired by Representative Ted Weiss (D-NY)

I was invited by the subcommittee to prepare testimony on the subject of technology transfer, and to comment on the potential conflicts of interest that arise in collaborations between universities and corporations in the context of research. My testimony discussed the process by which new ideas move from research institutions such as MIT, where their development is usually supported by public funds, into product development and production by manufacturers, which hope to profit from them.

In my remarks I discussed the inherent tension between university research and the fruitful application of the knowledge gained from that research, describing the consideration we at MIT have given to the issues involved. I also described some of the programs we have instituted, including the Industrial Liaison Program (ILP), and the studies we have undertaken that concern U.S. manufacturing and its productivity.

As the hearing continued, the subcommittee chose to raise other questions: whether research at MIT in fact benefits the manufacturers of other countries, particularly Japan, more than it does American manufacturers, and whether the ILP, as a fee-for-service activity, is ethical.

Subcommittee members criticized the ILP, which has operated here for 40 years, on two grounds: first, they saw it as providing, for a few, information and access to research in progress that U.S. corporations have already paid for through tax dollars, and, second, they were concerned that information was being made available to foreign corporations, who use it to compete against U.S. companies.

In reality, *all* of the research done on this campus is done openly and the results are published in the open literature, sooner rather than later. A corporation need not be a member of the ILP to obtain access to research in progress (although ILP membership does ease or facilitate the process somewhat), and a great deal of industrial contact with faculty and research staff occurs outside the structure of the ILP.

The facts are that our policy on technology transfer fosters the commercialization of MIT technology, while taking into account the need to support American industry and commerce. It encourages the application and practical use of some of the fruits of federally sponsored research at MIT, and it contributes to our national competitiveness in global markets. About 95 percent of our patent licenses are issued to U.S. companies, and whether our licenses are to U.S. or to foreign companies, we require substantial manufacture in the United States for products sold in this country.

The subcommittee's concern about foreign (specifically Japanese) access to the fruits of U.S. basic research is a reflection of widely shared and appropriate worries about our nation's ability to compete successfully in increasingly global markets. But in my view, improved U.S. competitiveness will *not* be achieved by attempting to restrict the flow of information, or the movement of people associated with basic research. It will be achieved by closer attention to the processes by which new ideas emerging in research are translated into new product developments, and by which these new products are manufactured.

The subcommittee had no patience with this perspective. But, in fact, MIT's concern with American manufacturing and its ability to compete on an increasingly global scale permeates much of our academic enterprise.

This concern resulted in another of this year's major achievements: the publication by the MIT Press of *Made in America: Regaining the Productive Edge*.

Made in America is the report of a 16-member faculty commission from science, engineering, economics and social science which I appointed in November of 1986. The MIT Commission on Industrial Productivity was asked to identify what has happened to U.S. industrial performance over the last several decades and what we and others might do to improve the situation.

The commission focused on eight major industrial sectors, conducting a worldwide, "factory-floor" examination of the sources of weaknesses in productivity. Members found six recurring patterns that adversely affect productivity in U.S. industry:

- Outdated strategies.
- Short time horizons.
- Technological weaknesses in development and production.
- Neglect of human resources.
- Failures of cooperation — within firms, between companies and suppliers, and among competitors.
- Industry and government at cross purposes.

The most productive firms in America, conversely, seem to have six key characteristics in common:

- Simultaneous improvement in quality, cost and delivery.
- Close relations with customers.
- Close relations with suppliers.
- The ability to use technology for strategic advantage.
- Flatter and less compartmentalized organizations.
- Innovative human resource policies.

One of the most important conclusions of the Commission was that if America is to remain the most productive nation on earth, we must transform the education of American managers and engineers. The report calls for greater emphasis on teamwork, and on real-world, hands-on experience in training engineers; for greater emphasis on language proficiency and international issues; and for better integration of technological, financial and human resources.

The report also calls for establishment of a major interdisciplinary research center on productivity here at MIT, where researchers would examine productivity not only in factories and service operations, but in the office, where half of working Americans spend two-thirds of their lives. It calls on the entire MIT community to increase its awareness of the critical problems surrounding national productivity and university education. Discussion of these suggestions will occur during the coming year.

We have already taken a very significant step in this regard. A year ago, we instituted a new masters degree program called Leaders for Manufacturing, developed under the leadership of Gerald L. Wilson, Dean of Engineering, and administered jointly by the School of Engineering and the Sloan School of Management. Eleven world-class manufacturing firms are partners in the effort, which admitted its second class of students this summer.

Leaders for Manufacturing is aimed at precisely the problems the Commission on Industrial Productivity has brought into such sharp focus. Its purpose is to define an educational experience that will yield graduates who are measurably more effective in managing large manufacturing organizations than are today's managers.

The focus of the program is on industrial teamwork. Students are carrying out their projects both in the classroom and in industrial settings, and our hope is that they will emerge from the program as agents for change.

A Personal Agenda

Let me turn now to my own agenda for the coming year, which will be my last as President of MIT.

I intend to focus my attention on three broad areas: the external forces affecting education and academia, the Institute's financial health, and our human resources.

Most, but not all, of the external forces influencing higher education originate on the banks of the Potomac. We must be alert and ready to speak out or take action when and as it becomes necessary in a number of areas. These include:

- Continuing efforts on both the federal and state levels to balance the budget, and what those efforts may do to support of education and research.
- New regulatory thrusts, on the federal, state and local levels, in such areas as animal rights, administration of financial aid, and a drug-free workplace and work force.
- The ramifications of continuing globalization of business, and of the increasing interconnection of world economies.
- Demographic trends, especially as they affect the student population.
- Compensation in several realms of university activity, including particularly the appointment of new faculty.

Second, I plan to devote a great deal of my time and attention to the Institute's financial health — both to reducing our operating deficit through the steps I outlined to you last spring and to increasing our capital base through the *Campaign for the future*. The campaign is doing very well indeed, as I note later in this report, with gifts and pledges amounting to \$417 million as of June 30. This progress is testimony to the prodigious and unflagging efforts of scores of volunteers and of a remarkable staff, led by Vice President and Treasurer Glenn P. Strehle.

With respect to our human resources — the core of the Institute's strength — I believe we must go beyond our traditional habit of recognizing individual ability and achievement. The diversity of talents, cultures, and points of view that characterizes this community deepens the well upon which we can draw for stimulation and re-invigoration, and I believe we must learn to value it accordingly.

The process of learning, in the research laboratory as well as in the classroom and library, is an intensely personal and individual one — and therefore can be a lonely one as well. The Institute's commitment to recognizing and rewarding merit and achievement, while essential, may increase that loneliness.

I have believed for some time that we ought to give greater emphasis to the idea of a *community* of learners, and that we should be more conscious of the ways in which all who study and work here affect the lives of others in the community. That means we need a greater awareness of the human differences that enrich this place. It means greater tolerance of, and respect for, those differences. And it means more conscious attention to the civilities that contribute so greatly to a community that is supportive of every human aspiration and hope, even as it celebrates individual achievement.

* * *

The poet of Ecclesiastes wrote, "In much wisdom is much grief, and he that increases knowledge increases sorrow." That is a sobering thought for an educator!

To *educate*, of course, means to lead out. From what, and to what, are matters for the educator to define. But it is obvious that education is not so much the explication of facts as of teaching students how to frame meaningful questions, how to proceed in seeking answers to questions never asked before, and to be wary of easy answers. I think this is particularly true at a science-based institution.

Thirty years ago, the greatest fear most Americans had was of nuclear war. Today, the prospects for peace seem much brighter, but the prospects for peace of mind do not. In place of the bomb we have a hole in the ozone layer.

In place of nuclear winter, we have the threat of global warming. In place of radioactive fallout, we have pollution of our rivers and oceans with industrial waste. We have manufactured more terrifying demons than we could have imagined in the 1950s. And at least in part, and in part correctly, the public blames science and technology.

Almost ten years ago, in my inaugural address, I said I believed what was needed in this country was "not a retreat from science and technology, but a more complete science and technology." What I meant was one that takes greater cognizance of the human context in which scientific and technological developments occur.

I believe that even more strongly today. And I believe we have hardly begun to achieve the goal.

That is the role of this institution. That MIT can help to forge a more complete science and technology, and is determined to do it, is what makes this place a national treasure.

**PAUL E. GRAY
September 1989**

In Special Recognition

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

Five MIT faculty members were elected to the National Academy of Engineering. Elected were: Ali S. Argon, Department of Mechanical Engineering; John D. C. Little, Sloan School of Management; Marvin L. Minsky, Department of Electrical Engineering and Computer Science; John N. Newman, Department of Ocean Engineering; and Henry I. Smith, Department of Electrical Engineering and Computer Science.

Five members of the MIT faculty were also nominated in the late spring as new Fellows of the American Academy of Arts and Sciences. Those nominated were: Richard R. Schrock, Department of Chemistry; Kenneth N. Stevens, Department of Electrical Engineering and Computer Science; Robert A. Weinberg, Department of Biology; Judith J. Thomson, Department of Linguistics and Philosophy; and Kenneth L. Hale, Department of Linguistics and Philosophy.

Alan H. Guth of the Department of Physics and Stephen J. Lippard of the Department of Chemistry were elected members of the National Academy of Sciences.

Two members of the MIT faculty were elected as foreign members of the USSR Academy of Sciences: Samuel C.C. Ting, Department of Physics and the Laboratory for Nuclear Engineering, and Edward N. Lorenz, Department of Earth, Atmospheric and Planetary Sciences. The only other professor at MIT who has been elected to the USSR Academy of Sciences is Institute Professor Emeritus Victor F. Weisskopf, Department of Physics.

Institute Professor Emeritus Harold E. "Doc" Edgerton received several awards last year including being one of 15 persons to receive the National Geographic Society Centennial Award, which acknowledges men and women who have devoted their lives to expanding knowledge of the earth and its inhabitants. He also received the National Medal of Technology from President Ronald Reagan for the invention of the electronic stroboscopic flash and for finding a multitude of applications for it within science, technology, and industry.

Dr. Nevin S. Scrimshaw, Institute Professor Emeritus and director of the International Food and Nutrition Program at MIT, received the eighth annual Bristol-Myers Award for Distinguished Achievement in Nutrition Research. Professor Scrimshaw was selected for the prize for his pioneering concept of the synergism between malnutrition and infection and as the developer of the first successful low-cost vegetable weaning formula for infants.

Professor Phillip A. Sharp of the Department of Biology and Director of the Center for Cancer Research was one of the recipients of the 1988 Albert Lasker Basic Medical Research Award. His citation reads in part, "for his remarkable discoveries and brilliant analysis of the mechanism of RNA splicing The processing activities of RNA are so fundamental to life that no area of medicine or biology will be untouched by the implications of Dr. Sharp's research."

Professor Sharp also was a co-recipient of the 1988 Louisa Gross Horwitz Prize, an award he shared with Professor Thomas R. Cech of the University of Colorado at Boulder. The Horwitz selection committee cited Dr. Sharp for his discovery that DNA is assembled in some cells by a kind of "cut and paste" method from lengths of DNA that contain numerous "nonsense" segments.

Institute Professor Emeritus Victor F. Weisskopf was one of two physicists to win the 1988 Enrico Fermi Award given by the Department of Energy. The award recognizes outstanding scientific and technical achievement in the development, use or control of atomic energy. Dr. Weisskopf was honored for his contributions to particle and nuclear physics.

Professors Vernon R. Young and Berthold K. P. Horn were both named winners of the prestigious prizes awarded by The Rank Foundation of England. Professor Young, professor of nutritional biochemistry, was cited for his work on the amino-acid metabolism of man, and Professor Horn, professor of electrical engineering and computer science, for his pioneering work which led to practical systems for computer vision.

Within the Institute, John S. Waugh, Department of Chemistry, and John D. C. Little, Sloan School of Management were appointed Institute Professors. The title of Institute Professor is an honor bestowed by the faculty on a colleague for leadership and distinguished accomplishments in the scholarly, educational, and general intellectual life of MIT and the wider academic community. Professor Waugh's principal studies have been in nuclear magnetic resonances (NMR), and his theory of coherent averaging has unified the understanding of many existing phenomena in NMR and also provided the conceptual base for the discovery of a variety of new ones.

Professor Little is widely recognized as the creator of the field of marketing science. As the ad hoc committee of the faculty reviewing Professor Little's nomination cited, "In the field of marketing science, which he virtually created and which became his main area of work, he wrote a number of original and important papers on the idea of optimal adaptive control marketing programs One of his colleagues has described his work in pulling together the behavioral and policy sciences fields in the Sloan School as 'heroic.' Another described him as a 'master teacher.'"

Professor Marvin L. Minsky, Department of Electrical Engineering and Computer Science, was selected as the 1989-90 recipient of the James R. Killian Jr. Faculty Achievement Award. Established in 1971 as a tribute to Dr. Killian, MIT's tenth President and former Chairman of the Corporation, the award recognizes extraordinary professional accomplishment and service to the Institute. The selection committee's citation described Professor Minsky as "one of the founding fathers of artificial intelligence" and said he has "exerted a marked influence on the field ever since," adding, "Sometimes a gadfly, he has produced a stream of provocative and controversial ideas which have shaped the identity and development of the field."

In the spring, John N. Tsitsiklis, Associate Professor of Electrical Engineering, was named the 1989 recipient of the Harold E. Edgerton Faculty Achievement Award. The award is given annually to a junior faculty member in recognition of exceptional distinction in teaching, research, and scholarship. The selection committee noted, "This year's recipient stands out for his excellence in cutting-edge research as well as his contributions to teaching."

* * *

This past year several key leadership roles at the Institute changed.

New department or program heads announced during the past year are: Jeanne S. Bamberger, Head, Music and Theatre Arts Section, Department of Humanities; David J. Benney, Head, Department of Mathematics; Sallie W. Chisholm, Director, MIT-Woods Hole Oceanographic Institution Joint Program in Oceanography and Oceanographic Engineering; T. Alan Hatton, Director, Chemical Engineering Practice School; Richard O. Hynes, Head, Department of Biology; Vernon M. Ingram, Director, Experimental Study Group; Jean E. Jackson, Head, Anthropology and Archaeology Section, Department of Humanities; Mujid S. Kazimi, Head, Department of Nuclear Engineering; Bruce Mazlish, Head, History Section, Department of Humanities; Wayne O'Neil, Head, Department of Linguistics and Philosophy; Paul L. Penfield Jr., Head, Department of Electrical Engineering and Computer Science; Peter C. B. Phillips, Director of the Statistics Center; Jeffrey H. Shapiro, Associate Head, Electrical Engineering and Computer Science; Kenneth A. Smith, Director, Whitaker College of Health Sciences and Technology; Jefferson W. Tester, Director, Energy Laboratory.

Major changes in the Institute's central administration during the year included the appointment or promotion of the following individuals: Isaac M. Colbert, Associate Dean of the Graduate School; Joseph S. Collins, Managing Director of Alumni Activities; Ellen Harris, Associate Provost for the Arts; Eric C. Johnson, Director, Corporate Relations; Patricia Kaurouma, Director of the Office of Minority Education; and Ronald P. Suduiko, Assistant to the President for Government and Community Relations.

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

Jacob P. Den Hartog died in March at the age of 87. Professor Emeritus in the Department of Mechanical Engineering, he was considered by his colleagues in the department as "the most important teacher of mechanical vibrations in the world." He made many original contributions to the solution of complex mechanical vibration problems in ships and large mechanical systems and his influence was worldwide.

Robert J. Holden, who served as associate dean of students for twenty years, died in December at the age of 71. As associate dean Mr. Holden had special responsibility for the freshman class, and he played a major role in developing counseling and orientation programs for the entering class. He retired from MIT in 1982.

Richard C. Lord, professor emeritus of chemistry at MIT and director emeritus of its Spectroscopy Laboratory, died in April at the age of 78. Dr. Lord was known for his research applying spectroscopy to the solution of chemical and biological problems. He also made widely recognized contributions to the interpretation of the infrared spectra of molecules in terms of their vibrational motion, and also to the understanding of the cohesion of molecules by means of hydrogen bonds.

Richard Stetson Morse died in July 1988 at the age of 76. An MIT graduate, he founded the National Research Corporation and served as its chief executive officer for 20 years and then as Assistant Secretary of the Army under Presidents Dwight D. Eisenhower and John F. Kennedy. He then returned to the Institute to teach a course in new enterprises at the Sloan School of Management. Dr. Morse retired from MIT in 1977.

Manfred Rauscher, an MIT graduate who stayed at the Institute to become one of the early teachers of aeronautical engineering for more than 20 years, died January 1988 in Switzerland at the age of 83. Dr. Rauscher, a leading authority on aircraft wing flutter and a renowned mathematician, taught at MIT until 1950 when he returned to his native Switzerland and a professorship in aeronautics at the Polytechnicum in Zurich.

Robert B. Semple, a Life Member Emeritus of the MIT Corporation, died in November at the age of 78. A 1932 graduate of MIT, Mr. Semple was named president of the Wyandotte Chemicals Corporation in 1949 and later was chairman of the BASF Wyandotte Corporation. He was elected to the Corporation in 1961 and to Life Membership in 1967, becoming emeritus in 1985.

Statistics for the Year

The following paragraphs report briefly on various aspects of the Institute's activities and operations during 1988–89.

Registration

In 1988–89 student enrollment was 9,500, compared with 9,565 in 1987–88. This total comprises 4,325 undergraduates (compared with 4,377 the previous year) and 5,175 graduate students (compared with 5,188 the previous year). The international student population was 1,964, representing 8 percent of the undergraduate and 31 percent of the graduate population. These students were citizens of 96 countries. Students with permanent resident status are included with U.S. citizens.

In 1988–89, there were 2,429 women students (1,412 undergraduate and 1,017 graduate) at the Institute, compared with 2,389 (1,384 undergraduate and 1,005 graduate) in 1987–88. In September 1988, 338 first-year women entered MIT, representing 34 percent of the freshman class.

In 1988–89, there were 1,637 minority students (1,331 undergraduate and 306 graduate) at the Institute, compared with 1,475 (1,236 undergraduate and 239 graduate) in 1987–88. Minority students included 332 Black Americans (non-Hispanic), 30 Native Americans, 353 Hispanic Americans, and 922 Asian Americans. The first-year class entering in September 1988 included 374 minority students, representing 38 percent of the class.

Degrees Awarded

Degrees awarded by the Institute in 1988–89 included 1,193 bachelor's degrees, 1,068 master's degrees, 41 engineer's degrees, and 492 doctoral degrees — a total of 2,794 (compared with 2,771 in 1987–88.)

Student Financial Aid

During the academic year 1988–89, the undergraduate student financial aid program was again characterized by an increase in the overall need for financial aid and in the aggregate amount of grants made available. There was an increase in the amount of MIT loans awarded, but Guaranteed Student Loans obtained from commercial sources decreased.

A total of 2,390 undergraduates who demonstrated the need for assistance (55 percent of the enrollment) received \$20,493,000 in grant aid and \$4,545,000 in loans. The total, \$25,038,000 represents a 19 percent increase in aid compared with last year.

Grant assistance to undergraduates was provided by \$6,410,000 in income from the scholarship endowment, by \$2,056,000 in outside gifts and Federal allocations to MIT for scholarships, and by \$3,478,000 in direct grants from outside sources, including ROTC, to needy students. In addition, \$8,549,000 in scholarships from MIT's unrestricted funds was provided to undergraduates, inclusive of the special program of scholarship aid to minority group students, which represented \$139,000, and the MIT Opportunity Awards, which accounted for \$256,000. An additional 626 students received grants from outside agencies, irrespective of need. The undergraduate scholarship endowment was increased by the addition of \$3,183,000 in new funds, raising the principal of the endowment by 6 percent, to \$53,998,000.

Loans totaling \$4,545,000 were made to needy undergraduates — a 40 percent increase from last year. Of this amount, \$912,000 came from the Technology Loan Fund and \$3,633,000 from the Perkins (formerly National Direct Student) Loan Fund. Not included in the foregoing summary is an additional \$3,495,000 obtained by undergraduates from state-administered Guaranteed Loan Programs and other outside sources.

Graduate students obtained \$2,066,000 from the Technology Loan Fund. In addition, \$691,000 was loaned by MIT under the Guaranteed Student Loan Program. The total, \$2,757,000, represents a 45 percent increase over last

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year's level. Graduate students obtained \$3,721,000 from outside sources under the Guaranteed Student Loan Program — 7 percent more than last year. The total loaned by MIT to both graduate and undergraduate students was \$7,302,000, a 43 percent increase over last year..

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

Career Services and Preprofessional Advising

This was a year when the demand for scientists and engineers could be described as broad rather than intense. Few industries were particularly hungry for talent — not surprising after six years of uninterrupted economic growth — but the number of employers with openings to fill made up for the lack of intensity. A total of 432 employers made recruiting visits, a near record. They included 413 companies and 19 government agencies. As in 1987–88, more than one in ten were financial houses and consulting firms interested in students with strong general skills rather than with specific training.

The number of students having interviews was the highest ever, approximately 1,830, compared with 1,635 the year before. The interview count is estimated at a little under 10,000.

The lack of intensity in the market was reflected in salary offers. In many disciplines starting salaries barely kept up with inflation. Thus, offers to bachelors rose 4.4 percent in mechanical engineering, 3.2 percent in electrical engineering, and 3.1 percent in computer science. The highest percentage gains at the bachelor's level were in aeronautical and astronautical engineering (up 6.4 percent), chemical engineering (up 7.0 percent) materials science and engineering (up 7.8 percent) and management (up 6.4 percent). It is not clear that any of these high percentages reflect a surge in demand. Special circumstances can be cited in each case. Offers to bachelors in aeronautical and astronautical engineering did not rise at all in 1987–88; there has been a shortfall of students in chemical engineering since the collapse in oil prices in 1982; and students in management have benefited from the high salaries offered by Wall Street houses and leading management consulting firms.

In most disciplines offers at the master's level rose less than those at the bachelor's level, and offers to Ph.D.'s rose even less. Thus, in electrical engineering offers to master's candidates rose only 2.6 percent, and offers to Ph.D.'s rose a bare 1 percent. In aeronautical and astronautical engineering offers to masters actually declined. The exception to this tale of offers declining with degree level is management. The Career Development Office at the Sloan School reports that the median offer to Sloan masters jumped 10 percent.

Contrary to the national trend, the number of MIT applicants to medical school rose significantly, to 131, compared with 111 in 1987–88. A jump in the number of alumni applicants was responsible for all of the increase. The 83 undergraduates who applied, and the 5 graduate students, represented a decrease from the year before. The 43 alumni applicants were up from 16 in 1987–88. To date, 87 percent of the undergraduates have been accepted, 80 percent of the graduate students, and 74 percent of the alumni. Almost certainly more candidates will be accepted before schools open in the fall.

Finances

As reported by the Vice President for Financial Operations and the Treasurer, the total financial operations of the Institute, including sponsored research, amounted to \$947,175,000, a decrease of 0.4 percent over 1987–88. The decrease in expenses results primarily from a reduction in subcontracts at the Lincoln Laboratory and the adoption by the Institute of depreciation accounting for buildings and equipment. Net of these changes, the programs of the Institute grew by 4.8 percent in total operating expenses. Education and general expenses — excluding the direct expenses of departmental and interdepartmental research and the Lincoln Laboratory — amounted to \$405,272,000 during 1988–89, compared with \$388,885,000 in 1987–88. The direct expenses of departmental and interdepartmental sponsored research on campus increased from \$194,418,000 to \$198,849,000, and direct expenses of the Lincoln Laboratory's sponsored research decreased from \$367,155,000 to \$343,054,000.

Current revenues used to meet the Institute's operating expenses totaled \$935,870,000, augmented by \$5,882,000 in current gifts and \$5,423,000 of other fund balances.

The major renovation work in the Julius A. Stratton Building (housing the Student Center) and the Plasma Fusion Center were substantially completed during the year. Work was begun to convert an existing building at 143 Albany Street to a graduate dormitory. New construction work for the expansion of the Rotch Library and the Bates Linear Accelerator was also begun. Stated on a comparable basis using depreciation accounting which was adopted in fiscal 1989, the book value of educational plant and equipment increased from \$248,246,000 to \$297,958,000.

At the end of the fiscal year, the Institute's investments, excluding retirement funds, student notes receivable, and amounts due from educational plant, had a book value of \$1,141,332,000 and a market value of \$1,064,202,000 and \$1,396,607,000 last year.

Gifts

Gifts, grants and bequests to MIT from private donors in 1988-89 were \$78,408,000. This is the Institute's second highest total and compares with \$83,710,000, the highest amount, received in 1987-88. The Alumni Fund reported gifts of \$14,407,000, a new high and 16 percent above the previous year.

The Institute announced the *Campaign for the future* on October 22, 1987, with \$210 million of gifts and pledges already committed. The campaign total was \$417 million on June 30, 1989. Much of this increase has been in pledges, which will add to the gift totals in the next several years as received. 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. Campaign events continue to be held both on and off campus to inform donors of the Institute's varied programs. The success of the campaign is attributable to the participation of the volunteers, faculty and staff.

Physical Plant and Campus Environment

Major design and construction activities this year included completion of the renovation of the lower floors of Julius A. Stratton Center; commencement of construction on the conversion of an existing mill building complex located at 143 Albany Street into a 190-bed graduate student residence; the long-awaited beginning of construction of an addition to the Rotch Architectural Library; completion of the Northeast Sector Master Plan covering an area of the main campus bounded by Main Street, Ames Street, Buildings 16/56/66, Buildings 26/36, and Vassar Street; and retention of an architect to begin design of a new biology building that will be located on a portion of the former TRW/Carr Fastener site at the corner of Main and Ames Streets. In addition, alterations to the east wing of the Nabisco Building for the Alcatraz C-Mod research cell and associated support facilities were completed as were renovation of the former bar and Riverside Lounge at the Faculty Club.

This year the Institute continued its commitment to energy conservation, with its attendant cost avoidance, by implementing a shared savings electricity conservation program in conjunction with Cambridge Electric Light Company. During the year, five energy service companies (ESCO's) retained by MIT installed conservation equipment and systems with a value in excess of \$4.3 million at no front-end cost to the Institute. Savings of some \$700,000 annually are currently being realized after shared savings payments of \$1.2 million have been made to the ESCo firms. The shared savings payments will continue for four to five years, after which time all savings will accrue to the Institute. Because of rapidly escalating water and sewer rates, water costs are beginning to challenge fuel and electricity in the Institute's overall utility budget. As a result of these economic pressures, the Institute is moving to reduce its water use by at least one-fourth with a broad conservation program patterned on the successful energy conservation programs of the last two decades.

Personnel Changes

CORPORATION

DEATHS

Robert B. Semple
Life Member, Emeritus

CHANGES OF APPOINTMENT

Irénée du Pont, Jr.
Life Member, Emeritus

John C. Haas
Life Member, Emeritus

Ellmore C. Patterson
Life Member, Emeritus

ELECTIONS

Karen W. Arenson
Member

Alexander V. d'Arbeloff
Member

Jennifer L. Lund
Member

Patrick J. McGovern
Member

Peter M. St. Germain
Member

Richard P. Simmons
Member

Mitchell W. Spellman
Member

Raymond S. Stata
Member

Dolores Wharton
Member

Edwin C. Whitehead
Life Member

T. A. Wilson
Life Member

MEMBERS EX-OFFICIO

Harris Weinstein
President
Alumni Association

TERMS EXPIRED

Donald J. Atwood
Member

E. R. Kane
Member

Margaret E. Mahoney
Member

Robert L. Mitchell
Member

Arlene Frances Roane
Member

FACULTY

DEATHS

Richard C. Lord
Department of Chemistry

RETIREMENTS

Stanley Backer
Professor
Department of Mechanical
Engineering

Judson R. Baron
Professor
Department of Aeronautics
and Astronautics

William F. Brace
Professor
Department of Earth,
Atmospheric, and Planetary
Sciences

Peter T. Demos
Professor
Department of Physics

Thomas H. Dupree
Professor
Department of Nuclear
Engineering

Herman N. Eisen
Professor
Department of Biology

James A. Fay
Professor
Department of Mechanical
Engineering

Jay W. Forrester
Professor
Sloan School of
Management

N. John Habraken
Professor
Department of Architecture

Marcus Karel
Professor
Department of Chemical
Engineering

James C. Keck
Professor
Department of Mechanical
Engineering

Richard Leacock
Professor
Media Arts and Sciences
Section

Jerome Y. Lettvin
Professor
Department of Biology

Irving M. London
Professor
Harvard-MIT Division of
Health Sciences and
Technology

Theodore H. H. Pian
Professor
Department of Aeronautics
and Astronautics

Irving E. Segal
Professor
Department of Mathematics

Annamaria Torriani-Gorini
Professor
Department of Biology

RESIGNATIONS

Professor

Gregory B. Baecher
Department of Civil
Engineering

Alvin J. Silk
Sloan School of
Management

Michele F. Vergne
Department of Mathematics

Martin L. Weitzman
Department of Economics

Associate Professor

Sarah J. Deutsch
History Section

Michael E. Geisler
Foreign Languages and
Literatures Section

John M. Hollerbach
Department of Brain and
Cognitive Sciences

Amy Lang
Literature Section

Richard K. Larson
Department of Linguistics
and Philosophy

Michael E. McGerr
History Section

William J. Paul
Literature Section

Donca Steriade
Department of Linguistics
and Philosophy

Paul E. Sullivan
Department of Ocean Engineering

Assistant Professor

Steven R. Bussolari
Department of Aeronautics
and Astronautics

Luis G. Casian
Department of Mathematics

Susan Cooper
Department of Physics

Frank R. Kardes
Sloan School of
Management

Don N. Kleinmuntz
Sloan School of
Management

Raphael C. Lee
Department of Electrical
Engineering and Computer
Science

Patricia C. O'Brien
Sloan School of
Management

C. Frederick Pearson
Department of Mathematics

Marilyn Richardson
Writing Program

Michael E. Treacy
Sloan School of
Management

Edith Waldstein
Foreign Languages and
Literatures Section

Stephane T. Zaleski
Department of Mathematics

PROMOTIONS

To Professor

Robert C. Armstrong
Department of Chemical
Engineering

Arvind
Department of Electrical
Engineering and Computer
Science

A. Nihat Berker
Department of Physics

Muriel R. Cooper
Media Arts and Sciences
Section

Peter S. Donaldson
Literature Section

Kerry A. Emanuel
Department of Earth,
Atmospheric, and Planetary
Sciences

Glenn R. Flierl
Department of Earth,
Atmospheric, and Planetary
Sciences

Woodie C. Flowers
Department of Mechanical
Engineering

Stephen C. Graves
Sloan School of
Management

John V. Guttag
Department of Electrical
Engineering and Computer
Science

Gary A. Hack
Department of Urban Studies
and Planning

David S. Jerison
Department of Mathematics

24 President

Roger D. Kamm
Department of Mechanical
Engineering

Stuart E. Madnick
Sloan School of
Management

James M. Poterba
Department of Economics

L. Raphael Reif
Department of Electrical
Engineering and Computer
Science

Charles F. Sabel
Department of Political
Science

Jefferson W. Tester
Department of Chemical
Engineering

Gregory J. Yurek
Department of Materials
Science and Engineering

To Associate Professor

Steven J. Burden
Department of Biology

Yet-Ming Chiang
Department of Materials
Science and Engineering

J. Brian Evans
Department of Earth,
Atmospheric, and Planetary
Sciences

James G. Fujimoto
Department of Electrical
Engineering and Computer
Science

W. Eric L. Grimson
Department of Electrical
Engineering and Computer
Science

Daniel E. Hastings
Department of Aeronautics
and Astronautics

Paul M. Healy
Sloan School of
Management

Richard K. Larson
Department of Linguistics
and Philosophy

Hae-Seung Lee
Department of Electrical
Engineering and Computer
Science

Michael E. Mc Gerr
History Section

Janos Polonyi
Department of Physics

Leigh H. Royden
Department of Earth,
Atmospheric, and Planetary
Sciences

Michael F. Rubner
Department of Materials
Science and Engineering

David A. Rudman
Department of Materials
Science and Engineering

H. Earl Ruley
Department of Biology

Biswapriya Sanyal
Department of Urban Studies
and Planning

Martin F. Schlecht
Department of Electrical
Engineering and Computer
Science

J. Mark Davidson Schuster
Department of Urban Studies
and Planning

Donca Steriade
Department of Linguistics
and Philosophy

Theoharis C. Theoharis
Literature Section

Ming-Kai Tse
Department of Mechanical
Engineering

Lena Valavani
Department of Aeronautics
and Astronautics

Nicholas Warner
Department of Mathematics

William E. Wehl
Department of Electrical
Engineering and Computer
Science

Jack Wisdom
Department of Earth,
Atmospheric, and Planetary
Sciences

Richard A. Young
Department of Biology

CHANGES OF APPOINTMENT

Michael Artin
Norbert Wiener Professor
Department of Mathematics

Ronald G. Ballinger
Carl Richard Soderberg
Associate Professor in Power
Engineering
Department of Nuclear
Engineering

Suzanne Berger
Department Head and Ford
International Professor of
Political Science
Department of Political
Science

Robert J. Birgeneau
Department Head and
Cecil and Ida Green
Professor of Physics
Department of Physics

Gabriel R. Bitran
Leaders for Manufacturing
Professor
Sloan School of
Management

Mary Boyce
Lynde and Harry Bradley
Foundation Career
Development Assistant
Professor
Department of Mechanical
Engineering

Robert A. Brown
Department Head and
Arthur D. Little Professor of
Chemical Engineering
Department of Chemical
Engineering

Stuart B. Brown
Richard P. Simmons
Assistant Professor of Metal
Processing and
Manufacturing
Department of Materials
Science and Engineering

Peggy Cebe
IBM Assistant Professor
Department of Materials
Science and Engineering

Joel P. Clark
Posco Professor of Materials
Science and Engineering
Department of Materials
Science and Engineering

Robert E. Cohen
Bayer Professor of Chemical
Engineering
Department of Chemical
Engineering

Peter A. Diamond
John and Jennie S.
MacDonald Professor and
Professor of Economics
Department of Economics

Mark Drela
Carl Richard Soderberg
Assistant Professor of Power
Engineering
Department of Nuclear
Engineering

Thomas W. Eager
Acting Department Head
Department of Materials
Science and Engineering

Jerome I. Friedman
William A. Coolidge
Professor of Physics
Department of Physics

Robert G. Gallager
Fujitsu Professor of Electrical
Engineering
Department of Electrical
Engineering and Computer
Science

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

John R. Hauser
Kirin Professor of Marketing
Sloan School of
Management

David Jewitt
Visiting Associate Professor
Department of Earth,
Atmospheric, and Planetary
Sciences

Thomas H. Jordan
Department Head and
Robert R. Shrock Professor
Department of Earth,
Atmospheric, and Planetary
Sciences

Jack L. Kerrebrock
Acting Dean of Engineering
School of Engineering

Thomas F. Knight
ITT Career Development
Assistant Professor
Department of Electrical
Engineering and Computer
Science

Thomas A. Kochan
Leaders for Manufacturing
Professor
Sloan School of
Management

John H. Lienhard
George N. Hatsopoulos
Assistant Professor
Department of Mechanical
Engineering

Rajnish Mehra
Visiting Professor of Finance
Sloan School of
Management

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

Seymour A. Papert
LEGO Professor of Learning
Research
Media Arts and Sciences
Section

Ronald R. Parker
Director, Plasma Fusion
Center, and Professor of
Electrical Engineering and
Computer Science
Department of Electrical
Engineering and Computer
Science

Peter Perdue
Ford International Career
Development Associate
Professor
History Section

26 President

William L. Porter
Department Head and
Professor
Department of Architecture

Emanuel M. Sachs
Rockwell International Career
Development Assistant
Professor
Department of Mechanical
Engineering

Richard L. Schmalensee
Gordon Y Billard Professor of
Economics and Management
Sloan School of
Management

Martin A. Schmidt
Joseph F. and Nancy P.
Keithley Career Development
Assistant Professor of
Electrical Engineering
Department of Electrical
Engineering and Computer
Science

John N. Slater
Visiting Assistant Professor
Department of Civil
Engineering

Kenneth A. Smith
Director of Whitaker College
of Health Sciences and
Technology and Associate
Provost and Vice President
for Research
Office of the Provost

Robert J. Thomas
Leaders for Manufacturing
Associate Professor
Sloan School of
Management

John E. Van Maanen
Erwin H. Schell Professor of
Organizational Studies
Sloan School of
Management

John S. Waugh
Institute Professor
Department of Chemistry

Roy E. Welsch
Leaders for Manufacturing
Professor
Sloan School of
Management

Bernhardt J. Wuensch
Director, Center for Materials
Science and Engineering,
and TDK Professor
Department of Materials
Science and Engineering

Kamal Youcef-Toumi
Carl Richard Soderberg
Assistant Professor in Power
Engineering
Department of Mechanical
Engineering

NEW APPOINTMENTS

Professor

Alan Brody
Professor
Music and Theater Arts
Section

Peter J. Huber
Professor
Department of Mathematics

Edward Levine
Professor
Department of Architecture

Alan P. Lightman
Professor
Writing Program

Julius Rebek, Jr.
Professor
Department of Chemistry

Paul L. Schechter
Professor
Department of Physics

Robert Stalnaker
Professor
Department of Linguistics
and Philosophy

Edwin L. Thomas
Professor
Department of Materials
Science and Engineering

Associate Professor

Haruhiko Asada
Associate Professor
Department of Mechanical
Engineering

James W. Axley
Associate Professor
Department of Architecture

Andrew Lo
Associate Professor
Sloan School of
Management

David Pesetsky
Associate Professor
Department of Linguistics
and Philosophy

Assistant Professor

Harold L. Alexander
Charles Stark Draper
Assistant Professor of
Aeronautics and Astronautics
Department of Aeronautics
and Astronautics

Karyn A. Altman
Assistant Professor of
Physical Education
Athletic Department

Anantaram Balakrishnan
Assistant Professor
Sloan School of
Management

Roland Benabou
Assistant Professor
Department of Economics

Dimitris Bertsimas
Assistant Professor
Sloan School of
Management

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

Benjamin H. Buchloh
Assistant Professor
Department of Architecture

Glorianna Davenport
Assistant Professor of Media
Technology
Media Arts and Sciences
Section and Department of
Architecture

Srinivas Devadas
Assistant Professor
Department of Electrical
Engineering and Computer
Science

Steven D. Eppinger
Assistant Professor
Sloan School of
Management

Deborah K. Fitzgerald
Assistant Professor
Program in Science,
Technology, and Society

Douglas J. Forsyth
Assistant Professor
History Section

Bernd Girod
Assistant Professor of Media
Technology
Media Arts and Sciences
Section

Michael J. Graves
Boeing Assistant Professor of
Aeronautics and Astronautics
Department of Aeronautics
and Astronautics

Alan D. Grossman
Assistant Professor
Department of Biology

Rebecca M. Henderson
Assistant Professor
Sloan School of
Management

Dan S. Henningson
Assistant Professor
Department of Mathematics

Ehud Hrushovski
Assistant Professor
Department of Mathematics

Mark J. Jakiela
Assistant Professor
Department of Mechanical
Engineering

Peter S. Kim
Assistant Professor
Department of Biology

Leila W. Kinney
Assistant Professor
Department of Architecture

Myrto Lefkopoulou
Assistant Professor
Harvard-MIT Division of
Health Sciences and
Technology

Ruth Lehmann
Assistant Professor
Department of Biology

Richard M. Locke
Assistant Professor
Sloan School of
Management

David Mc Allester
Assistant Professor
Department of Electrical
Engineering and Computer
Science

Steven E. Miller
Assistant Professor
Department of Political
Science

Richard G. Milner
Assistant Professor
Department of Physics

Leslie K. Norford
Assistant Professor
Department of Architecture

Wanda J. Orlikowski
Assistant Professor
Sloan School of
Management

James B. Rebitzer
Assistant Professor
Sloan School of
Management

Martin A. Schmidt
Assistant Professor
Department of Electrical
Engineering and Computer
Science

Stephan Schrader
Assistant Professor
Sloan School of
Management

Thomas Simmons
Assistant Professor
Writing Program

David L. Tennenhouse
KDD Career Development
Assistant Professor of
Computer Science and
Engineering
Department of Electrical
Engineering and Computer
Science

Michio Tsutsui
Assistant Professor of
Japanese
Foreign Languages and
Literatures Section

Marcie J. Tyre
Assistant Professor
Sloan School of
Management

28 President

Karl T. Ulrich
Assistant Professor
Sloan School of
Management

Andrew J. Whittle
Assistant Professor
Department of Civil
Engineering

Lyna L. Wiggins
Assistant Professor
Department of Urban Studies
and Planning

Zhenfang Zhou
Assistant Professor
Department of Mathematics

Adjunct Professor

Julian Keilson
Adjunct Professor
Sloan School of
Management

Butler W. Lampson
Adjunct Professor
Department of Electrical
Engineering and Computer
Science

Visiting Professor

Avraham Beja
Visiting Professor
Sloan School of
Management

Ari Ben-Menahem
Visiting Professor
Department of Earth,
Atmospheric, and Planetary
Sciences

Jeffrey Callen
Visiting Professor
Sloan School of
Management

Walter C. Carrington
Visiting Professor
School of Humanities and
Social Sciences

Judith Chafee
Visiting Professor
Department of Architecture

Hsing Chien Chang
Visiting Professor
Department of Materials
Science and Engineering

Jill K. Conway
Visiting Professor
School of Humanities and
Social Sciences

Charles M. Correa
Visiting Professor
Department of Architecture

Henry Elderfield
Visiting Professor
Department of Earth,
Atmospheric, and Planetary
Sciences

Elena Gascon-Vera
Visiting Professor
Foreign Languages and
Literatures Section

Martin Greenberger
Visiting Professor
Media Arts and Sciences
Section

Charles H. Holbrow
Visiting Professor
Spectroscopy Laboratory

Charles A. Holloway
Visiting Professor
Sloan School of
Management

Michael Kenstowicz
Visiting Professor
Department of Linguistics
and Philosophy

Wilfried Kurz
Visiting Professor
Department of Materials
Science and Engineering

Brigitte D. Lane
Visiting Professor
Foreign Languages and
Literatures Section

Jean P. Leinroth, Jr.
Visiting Professor
Department of Chemical
Engineering

Jan Karel Lenstra
Visiting Professor
Sloan School of
Management

Shimon Levit
Visiting Professor
Department of Physics

Jose A. D. Machuca
Visiting Professor
Sloan School of
Management

Shlomo Maital
Visiting Professor
Sloan School of
Management

Timothy Pedley
Visiting Professor
Department of Mechanical
Engineering

Victor Perez-Diaz
Visiting Professor
Department of Political
Science

Alexander M. Polyakov
Visiting Professor
Department of Physics

Remy Prud'homme
Visiting Professor
Department of Urban Studies
and Planning

Murray Sachs
Visiting Professor
Foreign Languages and
Literatures Section

Joseph F. Shea
Visiting Professor
Department of Aeronautics
and Astronautics

Nobumichi Shimizu
Visiting Professor
Department of Earth,
Atmospheric, and Planetary
Sciences

Hillel I. Shuval
Visiting Professor
Department of Civil
Engineering

Albert D. Wheelon
Visiting Professor
Program in Science,
Technology, and Society

Teng-Fong Wong
Visiting Professor
Department of Earth,
Atmospheric, and Planetary
Sciences

**Visiting Associate
Professor**

Alice H. Amsden
Visiting Associate Professor
Department of Urban Studies
and Planning

Stella R. Ashford
Visiting Associate Professor
Department of Mathematics

Pinhas Bar-Yoseph
Visiting Associate Professor
Department of Mechanical
Engineering

Martin A. Brody
Visiting Associate Professor
Music and Theater Arts
Section

John D. Denton
Visiting Associate Professor
Department of Aeronautics
and Astronautics

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

Sergio R. Jara-Diaz
Visiting Associate Professor
Department of Civil
Engineering

Paramasivam Jayachandran
Visiting Associate Professor
Department of Civil
Engineering

Alan D. Jepson
Visiting Associate Professor
Department of Brain and
Cognitive Sciences

Nancy G. Leveson
Visiting Associate Professor
Department of Electrical
Engineering and Computer
Science

Yvon Maday
Visiting Associate Professor
Department of Mechanical
Engineering

Anna B. Nagurney
Visiting Associate Professor
Department of Civil
Engineering

Philip D. Nicholson
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Department of Earth,
Atmospheric, and Planetary
Sciences

Chi-Sang Poon
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Harvard-MIT Division of
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Technology

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Department of Linguistics
and Philosophy

Harry L. Rosser
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Foreign Languages and
Literatures Section

Andy Ruina
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Department of Mechanical
Engineering

Omer Savas
Visiting Associate Professor
Department of Aeronautics
and Astronautics

Richard Schramm
Visiting Associate Professor
Department of Urban Studies
and Planning

Peter Schwartz
Visiting Associate Professor
Department of Mechanical
Engineering

Arisi S. J. Swamidas
Visiting Associate Professor
Department of Civil
Engineering

John B. Watkins
Visiting Associate Professor
Naval Science

Nobuhiko Yamasaki
Visiting Associate Professor
Department of Aeronautics
and Astronautics

Man K. Yau
Visiting Associate Professor
Department of Earth,
Atmospheric, and Planetary
Sciences

30 President

Visiting Assistant Professor

Rebecca Blank
Visiting Assistant Professor
Department of Economics

Michael E. Bradbury
Visiting Assistant Professor
Sloan School of
Management

Jorunn J. Buckley
Visiting Assistant Professor
Literature Section

Maristella Casciato
Visiting Assistant Professor
Department of Architecture

Zeynep Celik
Visiting Assistant Professor
Department of Architecture

Ronald D. Delahoussaye
Visiting Assistant Professor
Department of Mechanical
Engineering

Mathias Dewatripont
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Department of Economics

Ellen Fitzpatrick
Visiting Assistant Professor
History Section

Karen L. Fulbright
Visiting Assistant Professor
Department of Urban Studies
and Planning

Mendel Fygenon
Visiting Assistant Professor
Department of Mathematics

Yuhei Ichimaru
Visiting Assistant Professor
Harvard-M I T Division of
Health Sciences and
Technology

Edward N. Kaufman
Visiting Assistant Professor
Department of Architecture

Andrew Morrogh
Visiting Assistant Professor
Department of Architecture

June Namias
Visiting Assistant Professor
History Section

Kameshwar Poola
Visiting Assistant Professor
Department of Electrical
Engineering and Computer
Science

Patrick Rey
Visiting Assistant Professor
Department of Economics

Margaret E. Sokolik
Visiting Assistant Professor
Foreign Languages and
Literatures Section

Michael D. Woodford
Visiting Assistant Professor
Department of Economics

ADMINISTRATION

DEATHS

Marie-Christine B. Greenberg
Industrial Liaison Program

RETIREMENTS

Jacqueline S. Casey
Director, Design Services
Public Relations Services

Phyllis Cerrone
Administrative Assistant
Graphic Arts

Rodolfo S. Cid
Production Control
Scheduler
Operations and Systems

Ralph M. H. Coburn
Graphic Designer
Public Relations Services

Francis T. Conroy
Administrative Staff
Treasurer's Office

Mary Frances Daly
Administrative Assistant
Quarter Century Club

Anne M. Grazewski
Administrative Officer
Department of Political
Science

Reta M. Lee
Staff Accountant
Dean for Student Affairs

Norma B. Loomis
Provider/ Third Party Liaison
Officer
Medical Department

John I. Mattill
Editor, Technology Review
Alumni Association

Robert W. Mc Quillan
Assistant to the Comptroller
Comptroller's Accounting
Office

James F. Mc Taggart
Supervisor, Preventive
Maintenance
Superintendent's Office

D. Cosmo Papa
Facilities Officer
Department of Electrical
Engineering and Computer
Science

James N. Phinney
Senior District Director
National Campaign Office

Stanley N. Roach
Business Officer
Office of Laboratory Supplies

John R. Rogers
Associate Bursar/ Executive
Officer
Office of the Bursar

George K. Sankey
Special Assistant to the Vice
President
Vice President, Resource
Development

Ronald P. Smith
Associate Registrar
Registrar's Office

Robert M. Sullivan
Assistant Accounting Officer
Comptroller's Accounting
Office

Robert D. Taylor
Assistant Director
Property Office

John A. Tucker
Special Assistant to the
Department Head for VI-A
Program
Department of Electrical
Engineering and Computer
Science

Nancy R. Whitman
Librarian
Libraries

RESIGNATIONS

Amira L. Aaron
Associate Director for
Systems and Planning
Libraries

Ademola A. Aderibigbe
Consultant
Project Athena

Donald C. Alcaide
Applications Coordinator
Office of Facilities
Management Systems

Harold Ancell
Software/Hardware Analyst
Department of Electrical
Engineering and Computer
Science

Gregory R. Arsenault
Senior Analyst Programmer
Office of Financial Planning
and Management

Heather D. Ballinger
Fiscal Officer
Department of Materials
Science and Engineering

Stephen M. Bayle
Director of Information
Services
Vice President for Information
Systems

Kathleen Bielawski
Administrative Officer
History Section

Nora J. Bird
Librarian
Libraries

Bridget P. Blagbrough
Project Archivist
Libraries

Tim E. Bliamptis
Assistant to the Treasurer,
Investments
Treasurer's Office

Kim L. Bonfiglioli
Personnel Officer
Personnel Office

Marilyn Braithwaite
Assistant Dean, Student
Assistance Services
Dean for Student Affairs

Hope E. Brand
Librarian
Libraries

Leo F. Briody
Systems Programmer
Sloan School of
Management

William J. Bryant
Technical Writer
Project Athena

Cecilia M. Byrne
Direct Mail and Advertising
Manager
MIT Press

Sherry Hester Capano
Retirement Administrator
Personnel Office

William P. Cataldo
Senior Staff Accountant
Comptroller's Accounting
Office

Collette Chambers
Assistant to the Director
Telecommunications
Systems

Marc J. Chelemer
Senior Industrial Liaison
Officer
Industrial Liaison Program

Beverly R. Chew
Senior Consultant
Information Services

Eva L. Clarke
Administrative Assistant
Department of Civil
Engineering

June P. Coleman
Coordinator, Direct Mail
Program
Alumni Association

Angela N. Conley
Assistant Director
Admissions Office

32 President

Malcolm E. Cook
Applications Development
Programmer
Music and Theater Arts
Section

G. Rodger Crowe
Director of Development
School of Engineering

William Curr
Operations Administrator
Department of Biology

An-Ju Andrew Day
Analyst Programmer
Office of Facilities
Management Systems

Phillip B. Diver
Construction Coordinator
Physical Plant

Debra A. Edelstein
Editor
MIT Press

Toni Eika
Curatorial Assistant
Committee on the Visual Arts

Webb F. Elkins
Director of Alumni Relations
Secretary of Alumni
Association
Alumni Association

Clinton H. Elliott
Assistant Director
Admissions Office

Stephen C. Ellis
Senior Applications
Development Programmer
Project Athena

Rhea S. Epstein
Administrative Officer
Program in Science,
Technology, and Society

Roberta E. Fagin
Librarian
Libraries

Malkah B. Feldman
House Manager
Housing

Barbara M. Fienman
Assistant Dean, Residence
and Campus Activities
Dean for Student Affairs

Jean F. Gerlach
Technical Documentation
Specialist
Administrative Systems
Development

Mario L. Gnecco
Program Director,
Management of Technology
Program
Sloan School of
Management

Vincent S. Goodridge
Sergeant
Campus Police

Eugenia L. Gordon
Senior Analyst Programmer
Comptroller's Accounting
Office

H. Bredt Handy
Journals Editorial and
Production Manager
MIT Press

Patricia E. Harrison
Staff Writer/ Editor
Office of Communications

Lloyd M. Harte, Jr.
Auditor
Audit Division

David Hastings
Administrative Officer
Department of Applied
Biological Sciences

David M. Henry
Systems Programmer
Operations and Systems

Lyle A. Hodgson
Financial Administrator
Department of Physics

William F. Hogue
Assistant Director
Project Athena

Anita D. Horton
Assistant Director
Industrial Liaison Program

Jules M. Hurwitz
Consultant
Information Services

Yeong-Chang Hwang
Applications Development
Programmer
Project Athena

Bernadette J. Kay
Systems Programmer
Operations and Systems

Patricia A. Kellison
Microcomputer Training Lab
Coordinator
Information Services

A. Jon Kinnaman
Librarian
Libraries

F. Judith Klayman
Assistant Operations
Manager
Medical Department

Harriet Kounaves
Personnel Administrator
Department of Earth,
Atmospheric, and Planetary
Sciences

Mark E. Kriegsman
Consulting Assistant
Information Services

Daniel T. Langdale
Associate Director
Admissions Office

Michael J. Laudick
Assistant Director
Office of Development
Services

Patricia A. Leblanc-Gedney
Administrative Officer
Department of Ocean
Engineering

Mark H. Levine
Senior Systems Programmer
Project Athena

Katharyn L. Lieben
Documentation Manager
Project Athena

Virginia D. Lyons
Associate Director and Head
of the International Visitors
Office
Public Relations Services

Cathy A. Maretz
Journals Advertising and
Exhibits Manager
MIT Press

Kathleen L. Marshall
Assistant to the Executive
Director
Medical Department

Helvi M. McClelland
Executive Director, Council
for the Arts at MIT
Office of the President

Sue H. McKinley
Assistant to the Bursar -
Control and Accounting
Office of the Bursar

Deborah D. Myrick
Facilities Coordinator
Operations and Systems

Abigail Nelson
Administrative Assistant
Project Athena

Shava Nerad
Application Engineer
Information Services

Charles E. Neschke III
Systems Programmer
Project Athena

Kenneth Nies
Building Maintenance
Engineer
Physical Plant

Elizabeth A. Norton
Administrative Assistant,
Capital Gifts and Legal Affairs
Treasurer's Office

Marie J. O'Connor
Senior District Director
National Campaign Office

John J. O'Keefe, Jr.
Supervisor, Animal Facilities
Division of Comparative
Medicine

Dianne D. Overlan
Assistant Director for
Administration
Office of Campaign Systems

Karen Z. Pabon
Staff Associate, Student
Assistance Services
Dean for Student Affairs

Helen S. Pahigian
Librarian
Libraries

Irma L. Perez
Assistant Planning Officer
Planning Office

Oveta O. Perry
Personnel Administrator
Center for Cancer Research

Amy L. Porter
Technology Licensing Officer
Technology Licensing Office

Charlotte Golar Richie
Assistant Acquisition Editor
MIT Press

Victoria R. Risk
Assistant Manager,
Microcomputer Center
Information Services

Curtis B. Roads
Staff Writer/ Editor
MIT Press

Mark A. Roman
Systems Programmer
Operations and Systems

Mitchell A. Rosenberg
Industrial Liaison Officer
Industrial Liaison Program

Beth Ann Rosner
Circulation Manager,
Technology Review
Alumni Association

Italo Tony Rufo
Assistant Director
Office of Sponsored
Programs

Bonnie J. Schaefer
Contract Administrator
Office of Sponsored
Programs

Alan Schlingenbaum
Manager, Microcomputer
Center
Information Services

Anthony G. Scivetti
Architectural C A D Assistant
Office of Facilities
Management Systems

Margaret A. Shaw
Analyst Programmer
Administrative Systems
Development

34 President

Sheriefa Siers
Senior Analyst Programmer
Comptroller's Accounting
Office

Deborah A. Spence
Assistant Operations
Manager
Telecommunications
Systems

Jennifer G. Steiner
Systems Programmer
Project Athena

David J. Tenen
Analyst Programmer
Comptroller's Accounting
Office

Kiet Van Tran
Production Analyst
Operations and Systems

John B. Turner
Associate Dean
Dean of the Graduate School

Thomas Turner
Computer Operations
Coordinator
Whitaker College of Health
Sciences and Technology

Thomas F. Vacha
Superintendent of Building
Operations
Physical Plant

Alix Vasilatos
Systems Programmer
Operations and Systems

Susan Warshauer
Manager, Training and
Development Programs
Personnel Office

Federico Welsch
Research Development
Officer
Harvard-MIT Division of
Health Sciences and
Technology

Judith A. Whipple
Administrative Manager,
Experimental Music Studio
Media Laboratory

NEW APPOINTMENTS

Matthew Abbate
Editor
MIT Press

Khaled Y. Abou-Zaki
Auditor
Audit Division

Patricia F. Ahern
Librarian
Libraries

Miriam K. Ahmed
Designer
MIT Press

Ramona B. Alston
Personnel Officer
Personnel Office

T. Gregory Anderson
Associate Director for
Systems and Planning
Libraries

Edwards M. Andrews
Administrative Assistant, MIT
Supercomputer Facility
Office of the Provost

Robert C. Arnold
Senior Research Analyst
Office of Campaign Systems

Kathleen Avison
Benefits Counselor
Personnel Office

Donna Baranski-Walker
Technology Licensing Officer
Technology Licensing Office

Audrey E. Barr
Sales Representative
MIT Press

Emily W. Barrett
Assistant Director, Office of
Career Development
Sloan School of
Management

Claude C. R. Bellot
Administrative Assistant
Department of Electrical
Engineering and Computer
Science

Sharon L. Belville
Technical Writer
Project Athena

Andrew Bennett
Consultant
Information Services

John J. Bentley
Analyst Programmer
Lincoln Fiscal Office

Bruce M. Bernstein
Assistant Director
Admissions Office

Michael H. Bloom
Systems Programmer
Operations and Systems

Andrew D. Borthwick-Leslie
Technical Writer
Project Athena

Paul R. Bragger
House Manager
Housing

Daryl S. Brandt
Associate Head Librarian,
Engineering and Science
Libraries
Libraries

Richard L. Brewer
Manager of Administrative
Services
Environmental Medical
Service

David J. Brittan
Staff Writer/ Editor
Alumni Association

Dianne L. Brooks
Administrative Officer
History Section

William B. Bumpus
Analyst Programmer
Comptroller's Accounting
Office

Carolyn A. Bunker
Financial Officer
Office of the Bursar

Steven M. Burke
Assistant to the Dean
Dean for Student Affairs

Samuel D. Byrd III
Librarian
Libraries

Charles R. Carr
Senior Research Analyst
Office of Campaign Systems

Joy J. Carrigan
District Director
National Campaign Office

Patricia A. Carroll
Assistant Director
Student Financial Aid Office

Marie C. Cedrone
Administrative Officer
Leaders for Manufacturing
Program

Naomi F. Chase
Staff Writer/ Editor
Public Relations Services

Sandra Chauncey
Assistant Bursar/ Loan
Collection
Office of the Bursar

Jo-Anne M. Chute
Property Auditor
Property Office

Robert W. Coate
Supervisor, Operations
Center
Superintendent's Office

Malcolm E. Cook
Applications Development
Programmer
Music and Theater Arts
Section

Thomas J. Coppeto
Systems Programmer
Project Athena

Edward L. Courtney
Benefits Administration
Supervisor
Personnel Office

Vaughn Crayton
Engineering Assistant
Physical Plant

Phyllis Cerie
Computing Trainer
Information Services

William J. Cromie
Staff Writer/ Editor
Industrial Liaison Program

Kevin M. Cunningham
Technical Writer
Project Athena

James D'Innocenzo
Manager, Animal Facilities
Division of Comparative
Medicine

Roy A. Davey
Assistant Director,
Consortium Management
Office of Facilities
Management Systems

Peter J. Delaney
Manager / Systems
Administrator (5ESS)
Telecommunications
Systems

Colette P. Desmond
Assistant to the Director
Telecommunications
Systems

Diane M. Devlin
Assistant Director for
Purchasing Methods and
Procedures
Purchasing and Stores

John T. Dias
Analyst Programmer
Administrative Systems
Development

Mary T. Donovan
Analyst Programmer
Comptroller's Accounting
Office

Neal H. Dorow
Advisor to Fraternities and
Independent Living Groups
Dean for Student Affairs

Eileen G. Dorschner
Librarian
Libraries

Nanci A. Drago
Assistant Manager
Quarter Century Club

Paul Dworkin
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Project Athena

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Lincoln Fiscal Office

John E. Elsbree
Technical Writer
Project Athena

Eric P. Epstein
Engineering Assistant
Superintendent's Office

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Staff Writer/ Editor
Alumni Association

36 President

Kevin R. Fall
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Project Athena

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Industrial Liaison Program

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Sales Manager,
Microcomputer Center
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Journals Editorial and
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MIT Press

Carol J. Fleishauer
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Collection Management and
Technology
Libraries

Arthur J. Forrester
Assistant Director /
Subcontracting and
Government Relations
Purchasing and Stores

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Undergraduate Academic
Support Office
Dean for Student Affairs

Rod Garcia
Coordinator of Master's
Admissions
Sloan School of
Management

Brian Gardner
Applications Development
Programmer
Project Athena

Suzanna Garfunkel
Analyst Programmer
Comptroller's Accounting
Office

Robin Garner
Systems Programmer
Project Athena

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

James A. Gilbert
Exhibits Manager
MIT Press

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Analyst Programmer
Office of Campaign Systems

Barbara J. Goguen
Consultant
Information Services

Elizabeth A. Greene
Analyst Programmer
Comptroller's Accounting
Office

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Coordinator, Master's in City
Planning Program
Department of Urban Studies
and Planning

Jane E. Grussing
Coordinator for Graduate
Alumni Programs
Alumni Association

Danielle Guichard-Ashbrook
Staff Assistant for
International Students
Dean for Student Affairs

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

Phyllis F. Gutterman
Administrative Officer
Foreign Languages and
Literatures Section

Alice W. Hall
Librarian
Libraries

Evelynn Maxine Hammonds
Applications Development
Programmer
Project Athena

David M. Hardy
Analyst Programmer
Comptroller's Accounting
Office

Robert L. Harris
Route Supervisor, Building
Services
Superintendent's Office

Marcia A. Hartley
Manager of Parents Program
Alumni Association

V. Judson Harward
Applications Development
Programmer
Project Athena

Thomas S. Hoole
Staff Administrator,
Purchasing and Stores
Office of Laboratory Supplies

Barbara J. Hughes
Senior Consultant
Information Services

William F. Huxley
Technical Supervisor
Comptroller's Accounting
Office

William S. Irving
Audit Manager
Audit Division

Scott Jensen
Systems Programmer
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PROVOST

In my fourth report as Provost I would like to make a few observations about the past year and highlight some subjects that have been under study during the 1988-89 academic year and that should be resolved during the coming year.

The reports that follow discuss some of the past year's major activities and new initiatives in education, research, and support of our academic program. They are an indication of the continued high quality and commitment to excellence that are hallmarks of MIT.

1. The appointments of Ellen Harris, Associate Provost for the Arts and Visual Arts, Alan Brody, Director of Theatre Arts, and Edward Levine, Director of Visual Arts Program, carry great promise for our important initiatives in the arts which are being taken in response to the report of the faculty committee on the creative arts, chaired by Professor Paul Joskow.
2. The Institute's Retirement system has been successfully modified, but additional attention is needed for the special circumstances of tenured faculty because of the federally mandated lifting of the retirement cap.
3. The three- year budget outlook currently looks acceptable if we manage to stay within the stringent planning assumptions, for salary, tuition, self-help and research volume and, of course, if we continue to control expenditures. The adoption of a three-year "get well" budget program, which has successfully met projections at the FY 89 closing, is a major accomplishment of the year.
4. Construction began this summer on the Rotch Library addition, which will bring long- awaited and needed improvement to the architecture and visual arts library.
5. Faculty additions by school during the time period July 1, 1988 to June 30, 1989 are an important indication of the continued vitality of the Institute.

<u>School</u>	<u>Untenured</u>	<u>Tenured</u>
Architecture & Planning	7	1
Engineering	13	1
Humanities & Social Science	5	1
Science	8	2
Sloan School	11	-
HST/Whitaker/Brain & Cognitive Science	-	-

In the remainder of this report I would like to note some of the important issues which I hope will be discussed and resolved during the coming year. With a single exception, all of these issues have been the subject of on-going studies which have involved very considerable effort during the past year. We should be very grateful to the faculty, students and staff who have devoted their time and concern to these subjects.

1. The Residence/Orientation Committee, chaired by Professor Molly Potter, will report on the undergraduate orientation and residence system and make recommendations on possible changes.
2. Lincoln Laboratory Committee. This committee, chaired by Professor Joel Moses, has been reviewing, for the first time since 1972, the desirability of continued MIT sponsorship of Lincoln Laboratory. This Committee will report to the faculty and make recommendations to the President.
3. Technology Policy Studies. Under the chairmanship of Professor Joel Clark, a faculty group has been considering the desirability of an initiative on policy studies at MIT. Their recommendations will be made this fall and I anticipate that appropriate action will be taken.

4. Evaluation of Academic Computing and Project Athena. A very important task is underway under the leadership of Dean Margaret MacVicar to evaluate the success of Project Athena and to examine the future path for academic computing at MIT. The impetus for this effort is the planned end of this phase of the IBM/DEC/MIT collaborative agreement.

5. The Campaign for the Future. We are entering the third year of what promises to be a successful Campaign. Sometime during the year it will be helpful to compare the results of the Campaign to the priorities which were originally set by the Campaign sub-group of the Academic Council.

6. MIT's International Relationships. In recent months there has been a growing public outcry about several aspects of the international relationships of leading US research universities, especially MIT. This criticism includes (1) accepting foreign science and engineering graduate students and visitors, (2) licensing intellectual property to foreign corporations and (3) stimulating interest through ILP and other mechanisms in MIT research accomplishments. It is clear that MIT should devote some thought to the desired international posture of the Institute given the current global environment and to articulate a policy for the Institute. It is my intention to ask a faculty group to begin a study of this important subject in the fall.

7. President Paul Gray and I are strongly committed to the Affirmative Action Program of the Institute. As I have noted in past reports, the record of attracting qualified underrepresented minorities and women to the faculty is simply not adequate. During the past year, with the assistance of the Institute Equal Opportunity Committee under the Chairmanship of Professor Herman Feshbach, we have begun a new initiative in collaboration initially with eight other universities which we hope will make a significant contribution to increasing the supply of underrepresented minority scholars in science and engineering who intend to pursue Ph.D. studies and eventually academic careers. This is an example of the several different efforts which MIT should continue to mount in order to preserve its leadership position and attitude towards valuing difference in our community.

JOHN M. DEUTCH

Libraries

"The MIT Libraries at the Beginning of the 21st Century -- A Strategic Plan", was issued in December 1988. It was the culmination of an effort that began in the summer of 1987 and was the collective effort of many members of the Libraries' staff. Publication of this report is one of the most significant events in the recent history of the MIT Libraries as it provides a framework for future development of services, collections, and facilities. The strategic plan included a number of major components: a vision of the Libraries in the year 2001; a statement of organizational values and philosophy that describes changes of emphasis and direction; an analysis of the environment in which the Libraries operates with an identification of major trends affecting collections, services, technology, finances, and the Institute as an educational and research institution; a comparison of the MIT Libraries with the libraries of other research institutions; and, of singular importance, a set of directions and strategies for the next decade.

The "Directions and Strategies" section of the strategic plan develops a number of directions the Libraries will take with regard to collections, services, space, the use of technology, personnel, and organization. In services and collections, the major pieces are a self-study of information services; expansion of the online catalogue to include information on all materials in the Libraries regardless of format; marketing and publicity; promoting interactions between librarians and faculty, students, and research staff; and intensified cooperation with other libraries. Under technology, the directions include improving electronic linkages among the Libraries, its users, and remote information sources; continued automation of internal operations; exploitation of new technologies; and increased collaboration within and outside of MIT in technological innovation. For the staff, there is a need for maintaining a competitive salary program; improving recruitment and training; and strengthening the quality of management and leadership. The "library as place" concept requires that everything possible be done to improve the utility, comfort, and attractiveness of existing space for staff, users and collections as well as imaginative adaptation of space for new technological requirements. Financial directions include the establishment of a discretionary fund to support innovative services and new programs; greater use of cost analysis; and significant growth in fund raising and development activities. Another major direction entitled "Streamlining" calls for the identification and elimination of non-essential or redundant activities; adherence to national standards that provide better service or cost savings and the development of local standards for quality control. The final direction, "Systemization", emphasizes the importance of establishing common directions in the libraries, and using library staff and resources in the most effective way, in order to provide the best possible service to the user community.

The Strategic Plan includes a long list of activities, projects and studies to be completed over the next five years. Many of the projects will be supported by the reallocation of existing resources, by foundation and government grants, or by a combination of the two. Two major efforts were identified as having the highest priority for the immediate future -- retrospective conversion and databases on the campus network. The Libraries have been allocating funds from the Sustaining Fellows Program to fund the first of these in part. A combination of library funds plus equipment and programming provided by Information Systems will cover the second.

The goal of retrospective conversion is to add to Barton, the Libraries' online catalogue, records for materials acquired in the period 1964-1974. The addition of approximately 200,000 records for books, serials, theses, and other materials will

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complement the more than 400,000 current records covering materials acquired from 1974 to date. Ultimately, materials acquired prior to 1964 will also be added to the system with architecture and urban planning being the first disciplines affected.

By the end of 1989, it is planned that the Libraries' online catalogue will be available on the campus network. It is already accessible through dial access. It is expected that within the same time period, a database of current periodical titles will also be mounted on the network. This will be a table of contents file, searchable by journal title, author, and subject, and the system will include a document delivery component.

During the past year, actions were undertaken and decisions were made that supported the overall direction of the plan and laid the foundation for future programs. These will be reported in fuller detail below and include the serials cancellation project, expansion of the online system, acquisition of CD-ROM databases, literature searching for undergraduates, the Rotch Library addition, Project Athena clusters, electronic library modules, and the decentralization of journals receipt. Efforts in most of these areas will continue into FY1990 and beyond. In addition, during the year beginning July 1, 1989, several new major projects and programs will be undertaken including a space study of the second floor technical services area in Hayden Library, renovation of Dewey Library to accommodate a microform area and staff offices, implementation of decentralized serials checking, and an increased emphasis on fund raising. These are in addition, of course, to retrospective conversion, databases on the network, and the upgrade of the online system.

SERVICES AND COLLECTIONS

The serials cancellation project that was undertaken during the 1987/88 academic year, concluded in the fall of 1988. The goals of the project were to provide budgetary control over serials, to provide funds for the purchase of new serial titles including those in electronic format, and maintenance of the existing level of funding for the purchase of monographs. The project involved several review strategies. The highest priced titles were examined first along with those with the greatest percentage of increase over the previous year. Surveys of lower priced titles as well as the few remaining duplicates followed. Specialized abstracting and indexing services were also reviewed to see whether similar information might be available through other print or online sources. Holdings of other Boston area libraries were considered as were the results of extensive discussion of individual titles with faculty members. The result of the project was the cancellation of approximately 5% of MIT's titles, representing about 10% of the serials budget. The three goals of the project stated above were realized without serious undermining of the quality of the collections. The Libraries will continue to monitor prices, usage, interlibrary loan requests, and online database searching requests. Significant levels of activity for any title may result in reinstatement of that subscription.

At a broader level, efforts are continuing among academic and research librarians, to develop a strategy for dealing with the longer terms issues inherent in the serials pricing crisis. The Association of Research Libraries issued two reports late in the spring of 1989 that reported on price escalation and on publishing practices. ARL has initiated a large scale effort involving research libraries, learned societies, and university administrations, to address the deeper intellectual and economic issues. While the serial price increase spiral seems to have slowed down somewhat during the past year, this is likely to be of short duration. MIT will continue to participate in multiple efforts aimed at a long term solution to this most difficult problem.

The Computerized Literature Search Service reports a number of interesting changes and developments in the use of its services. As the Libraries move toward a more technologically sophisticated and user-focused environment, CLSS has found itself shifting its focus from "pure" online searching to more involvement with experimentation and evaluation of information products and user services. They have seen an increase in "exceptional" searches as the more straightforward variety is handled by the divisional and branch libraries through online searching, CD-ROM products, or end-user searching. CLSS has been asked for searches that are of exceptional length or those requiring the use of many databases. There is an increasing number of "bibliometric" searches that require the statistical analysis of the literature of a field. There has been an increase in requests for searches in Barton and in the online catalogues of other libraries. An increased amount of time is being spent on designing and executing results by various electronic means including downloading to disk, local printing, or delivery on diskette. During the next year, CLSS will be investigating the use of MIT's new telephone system for information transfer. Full text searching is in great demand, especially for business and newspaper sources. There has also been a marked increase in patent searching for both the MIT Technology Licensing Office and for outside clients. All of these developments demonstrate how much and how quickly the online searching environment is changing at MIT and beyond. The relationship of these changes to the public service units and to the future development of the Computerized Literature Search Service will be a key element in the forthcoming information services study.

Among the other events of note was the publication of the first issue of MIT Libraries' News; a Report to the Faculty. The inaugural number included articles on the strategic plan, serials costs, and electronic access to the Libraries. The newsletter also reported on a new experiment under which MIT senior undergraduates writing theses are provided with free computerized literature searching. It is likely that this service will be made a permanent program within the Libraries and may eventually be extended to all undergraduates. Two major policy statements were issued during the year. The first deals with the Libraries' storage policy and covers the transfer of less used collections to the RetroSpective Collection and to the Harvard Depository. The policy insures that both the intellectual issues of user needs and collection integrity and the physical issue of preservation will be considered as transfer decisions are made. A second statement defined rare book collections in the MIT Libraries in terms of scope, staff responsibility, acquisition, and bibliographic processing. The Task Force on Fee-Based Services completed its charge by delivering a report which essentially recommended that MIT not undertake the establishment of a separate fee-for-service operation at this time. The report recommended that existing services be continued and expanded and that the question be examined again at some point in the near future. In a continuing effort to improve access to the collections, bibliographic records for all purchased monographs awaiting processing were input to the online catalogue.

While collections of scholarly books, journals, and manuscripts are the heart of any research library, it is often the odd collection that attracts attention. An example of this occurred last year when Tech Talk, the official weekly MIT newsletter, published an article on a collection called the "Archives of Useless Research." This collection, originally the property of Scientific American, and expanded through donations by MIT faculty and by unsolicited gifts, contains a wide spectrum of writings that can be best characterized as "unscientific science" or "speculative science" or "crackpot science." Between December, 1988 and May, 1989, staff of the Institute Archives which has responsibility for the collection were interviewed by reporters from United Press International, the Associated Press, Reuters, the Boston Globe, and several New England Newspapers. The press release appeared in papers from Los Angeles to Beijing. A number of radio talk-show hosts requested interviews and there was a segment on National Public

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Radio's "Weekend Edition." Interviews were also arranged by radio stations in Canada and Australia, and by the Voice of America.

In keeping with the Libraries' efforts to strengthen collections that are used heavily by undergraduates, two areas were identified for additional support during the year. The first was the development of a collection on popular medicine and community health in the Schering-Plough Library. The second is the general area of science and technology for the non-specialist.

The collections were enriched by a number of gifts during the year. The Cambridge-based firm, Bolt, Beranek and Newman, donated 800 monographs in the fields of electrical engineering, computer science and acoustics. A major collection of political science books belonging to the late Professor Harold Isaacs was donated by his widow along with his personal papers. An endowed book fund in Professor Isaacs' memory was also established. Professor Gian-Carlo Rota made a second major gift of 2,400 books in mathematics, philosophy, and literature. Franziska Hosken gave MIT a collection of over 1,000 planning studies. The Institute Archives acquired a number of collections including the papers of Benson Snyder, former Dean for Institute Relations and Director of the Division for Study and Research in Education; the MIT Alumni Association; and the Daedalus Project in which students and faculty established a new world record for human-powered flight. Papers of several faculty members were added to the manuscript collections: David Waugh, biology; Hurd Willett, meteorology; David Botstein, genetics; and Charles Kindleberger, economic history and international monetary systems.

TECHNOLOGY

The expansion of the Libraries' online information system is a cornerstone of the strategic plan and a critical element in many future plans. Of primary importance is the need to increase the number of public access terminals in anticipation of a greatly expanded database resulting from retrospective conversion. The completion of retrospective conversion will also require the establishment of an online system to achieve greater consistency in catalogue entries. Finally, the automation of the acquisitions process has a high priority in the plan. These objectives combined with providing both dial-in access and remote access through the campus network clearly establish the need for a system with greatly increased capacity. Originally, the Libraries planned to expand the system through the acquisition of an additional Geac computer. After considerable discussion and evaluation of alternatives, however, a decision was made to move the online catalogue to a CD-ROM environment. This will provide a number of benefits: the reduced burden on the existing system would enable the Libraries to add functionality without having to acquire an additional computer; the CD-ROM catalogues will provide much more sophisticated searching including the use of Boolean operators at a relatively low cost; the CD-ROM catalogue system will be transferable to another online configuration.

The plan is to replace Geac public catalogue terminals with CD-ROM workstations. Each station will be served by compact disk containing the bulk of the catalogue, supplemented by a hard disk that will include circulation status and updated bibliographic records. The CD will be re-mastered every three to four months. It is anticipated that a Local Area Network (LAN) will be needed in order to link the workstations throughout the Libraries. The LAN would also serve as a gateway to the general campus network and the various databases available at MIT. The two requirements most critical to the success of this endeavor, currency of the bibliographic data and circulation status that is accurate on a daily basis, require that the MIT Libraries work closely with whichever CD-ROM vendor is selected for the project, since these features are not currently widely implemented in the CD-ROM marketplace.

A number of cooperative efforts between the Libraries and Information Systems moved ahead during the year. A cluster of Project Athena workstations were installed in the Barker Engineering Library and another set will be installed shortly in the basement of Hayden Library. The availability of these terminals will not only enhance student access to the Athena network, but will also provide a link between Athena and the Libraries' online system. The Hayden cluster will have the additional advantage of being accessible 24 hours per day to the MIT community. Planning continued for mounting both the online catalogue and a table of contents and other databases on the campus network.

There were a number of other achievements in the general area of technology:

- Dial access to Barton was formally opened to the MIT community and to the scholarly world at large, and has been extensively used without any disruptive effects on internal response time.
- Dial access is now available to the online catalogues of a number of Boston area libraries including Harvard, Boston College, Boston University, Brandeis University and Tufts University. The Boston Library Consortium has received a grant from the State of Massachusetts to investigate the use of an open systems interface (OSI) to link all of the online catalogues of its members.
- The number of CD-ROM databases available in the Libraries continues to increase. The availability of LotusOne Source in the Dewey Library has greatly increased the use of that library. Among the other files that are available are Academic Index, Science Citation Index, NTIS, Supermap, Public Affairs Information Service, and Art Index.
- BITNET access was provided for the senior library administration.
- The Microreproduction Laboratory acquired a microfiche enlarger that utilizes a laser scanner and printer. This unit will result in substantial savings in labor and production costs and permit greater user of existing collections of microfiche, especially MIT theses.

STAFF

Two new associate directors joined the staff during the past year. Carol Fleishauer, formerly head of acquisitions at Stanford University, became Associate Director for Collection Management and Technical Services in October, 1988. Greg Anderson was appointed Associate Director for Systems and Planning in March, 1989. He came to MIT from the University of Georgia. Shirley K. Baker, Associate Director for Public Services since 1981, joined the ranks of former MIT staff who direct major research libraries when she was appointed Dean of Libraries at Washington University in St. Louis, effective August 1, 1989.

Ruth K. Seidman, Head of the Engineering and Science Libraries, was elected vice-president and president-elect of Special Libraries Association.

Nancy Whitman, a member of the librarian staff for a number of years, and most recently Acting Librarian of the Lindgren Library, retired from the Institute.

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AFFIRMATIVE ACTION

The most recent data collected by the Office of Library Personnel Resources of the American Library Association indicated that approximately 13% of the entry level librarians working in U.S. libraries were minorities. This was last reported in 1985. In 1987 and 1988 surveys, however, the minority enrollment in U.S. graduate library schools was only 6.8%. Library school data also indicates that relatively few minority librarians are geographically mobile, and that a majority of them plan to work in school libraries and public libraries. Despite the declining number of minority librarians entering the profession, the MIT Libraries were able to hire one minority librarian during 1988/89, raising the total number of minorities in professional positions to four.

During the year, there were 11 searches for professional staff. In these searches there was a total of 226 candidates of which seven were identified as minorities and only four were under-represented minorities. One of these individuals was hired; a second was offered a position but declined.

In order to attract additional minority candidates for our pools, the Associate Director for Administration visited the Atlanta University library school last year. This is one of the two schools with a predominantly minority enrollment. He met with students and faculty and will retain close contact with this school and with others with potential minority candidates. As a result of contact with library schools, a minority candidate was referred to MIT by Simmons College. He was subsequently interviewed and offered a position. He will be joining the staff of the Science Library in September, 1989.

SPACE

The long awaited commencement of construction for the addition to Rotch Library began in late spring of 1989. Current plans call for the completion of the addition by late spring of 1990 with the renovation of the existing space to follow. Occupancy of the full library is expected for September, 1990. The major activities connected with this project that will take place during the 1989/90 year include stack specification and order; office layout; and furniture and equipment specification and order. In addition, plans will be developed for the operation of the library during the renovation of the existing space and for the relocation of materials and functions that eventually will be located there.

In Hayden Library, the Systems Office staff was relocated to the space formerly used as a conference room and the Computer Room was renovated to accommodate a new air conditioning unit. The new Systems Office has, in addition to staff offices, a training room for Barton operations and other technology-related activities.

ORGANIZATION

One of the pivotal elements in the Libraries' strategic plan is the goal of developing a greater sense of "systemness". It includes providing increased opportunity for a closer working relationship and for better communication between and among the several functional areas, especially between technical and public services. A most significant step in that direction was taken when the newly formed Technical Services and Collections Committee (TSAC) that includes the four department heads reporting to the Associate Director for Collection Management and Technical Services, began meeting on a regular basis with the Divisional Librarians Group (heads of the major public services units) under the leadership of the two associate directors.

Following the successful development of the strategic plan for the MIT Libraries, a major effort was undertaken during the spring of 1989 in the area of departmental planning. Members of Library Council, the management group consisting of department heads, the associate directors and the director, developed plans for their respective areas that were then reviewed at a day-long planning retreat. Departmental plans will be incorporated into the updated strategic plan and the process will become an integral part of the annual planning cycle.

A primary example of the Libraries' commitment to streamlining of its operations was the decision made during the year to cease duplicate handling of journal receipts, effective January 1, 1990. At present, all journals are received centrally in the Acquisitions Department where they are processed and then are sent to the appropriate divisional or branch library and are processed a second time. A staff group is currently planning for the direct delivery of journals to the public service units, eliminating the central check-in process. The new procedures will result in a more timely availability of current journals as well as savings in staff effort.

CONCLUSION

The year just concluded has been one with a tremendous amount of progress for the Libraries. The publication of the strategic plan, the planning of the addition to Rotch, expansion of the online system, the formation and work of a dozen search committees, and a host of other projects and programs, were carried out with great efficiency, imagination, a strong sense of cooperation and community, and a lot of hard work. All of the staff are to be congratulated on another successful year.

JAY K. LUCKER

Lincoln Laboratory

LINCOLN LABORATORY

Lincoln Laboratory is operated by MIT as a Federal Contract Research 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 95 percent of the Laboratory's budgetary support. The Federal Aviation Administration provided most of the non-DoD support. In fiscal year 1988 the operating budget was \$425 million, supporting the efforts of 847 professional staff, 83% of whom hold advanced degrees.

The following administrative changes at the Laboratory Steering Committee level occurred during the year: Vincent Vitto and Vincent W. S. Chan became Head and Associate Head of Division 6, respectively; Anthony F. Pensa became Associate Head of Division 9; and Walter I. Wells became Assistant to the Director.

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

Terminal Air Traffic Control Automation

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

Lincoln Laboratory will develop new procedures, new automation software, centralized planning techniques, and means to enhance strategic and tactical coordination among these team members. All of these techniques will rely on advanced controller-interface technology. A simulation facility will be developed at the Laboratory to evaluate candidate automation techniques. Promising techniques will then undergo live operational evaluation in the Boston terminal area.

Hazardous Weather Detection

A multi-year program in radar sensing of hazardous weather employs experimental test-bed radars with advanced signal and data processing capabilities to develop and validate systems for automatically providing weather warnings to air traffic controllers and pilots. The Laboratory-developed wind shear and turbulence detection algorithms will be utilized in the Terminal Doppler Weather Radar (TDWR) and terminal NEXRAD systems to be deployed at major airports starting in 1990. Additionally the Laboratory is investigating the use of Air Surveillance Radars to provide hazardous weather information for smaller airports.

Measurements have been carried out in a number of different locations using the test-bed radars in conjunction with other weather radars, automatic surface observations stations and instrumented aircraft. The TDWR test bed was successful in a real-time operational demonstration of wind shear warning products at Denver's Stapleton Airport in 1988. The FAA has commenced the production of 45 TDWR systems. The Laboratory assisted in the TDWR technical requirements specification development and proposal evaluation, and is assisting in program monitoring as well as system refinement.

Radar Surveillance Technology Program (RST)

The RST program is a Navy-sponsored activity to identify, develop, and demonstrate the surveillance radar concepts and technologies required to upgrade surface fleet defenses. The program activities supporting this objective include systems analyses in the radar configuration, ECCM, target parameter estimation, and false-alarm control areas. The hardware emphasis currently is placed on an ultra-low azimuth sidelobe planar array antenna with digital adaptive nulling in elevation, a solid-state transmitter with exceptional phase stability and a digital adaptive beamforming processor. The subsystems will be assembled into a test-bed radar for target detection, jammer-suppression, and clutter-rejection experiments. A proof of concept demonstration, using the test-bed radar and other Navy sensor elements, is being planned in 1992.

U.S. Army Kwajalein Atoll (USAKA) Program

Under a long-running Army program, scientific direction is provided for the four instrumentation radars which comprise the Kiernan Re-Entry Measurements Site (KREMS) at the U.S. Army Kwajalein Atoll (USAKA). The radars provide signature and metric measurements on missile systems and satellites which support the offense, defense, and space surveillance communities.

The support provided by MIT includes test planning, management of operations, data reduction, and the design of modifications needed for new user requirements or improved performance.

The four radars operate at VHF, UHF, L, S and C-band, 35 GHz and 95 GHz. Although some are quite old, the continuing modification effort has kept them at the forefront of technology. They offer outstanding sensitivity, accuracy and waveform flexibility and a combined capability to characterize targets which is found nowhere else in the world.

Optical Aircraft Measurements Program (OAMP)

For several years, Lincoln Laboratory has been responsible for the development of an airborne infra-red sensor to be used in gathering high quality infra-red data in support of research in ballistic missile defense. Sponsored by the U.S. Army Strategic Defense Command, the program development included extensive modification of an RC-135 aircraft as the sensor platform. The aircraft was provided and modified by the Air Force Logistics Command.

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

The aircraft/sensor system has been named COBRA EYE. Integration and test of COBRA EYE was completed in the Spring of 1989. Operator crews have been trained, operation and maintenance support has been provided and preparations have been made for the recovery and analysis of data at Lincoln Laboratory.

Speech Enhancement for HF AM Radio Transmission

A new approach to speech enhancement has been developed by the Speech Systems Technology Group for increasing effective broadcast range in the Voice of America broadcast system. The approach uses a sinusoidal analysis/synthesis framework, and integrates phase dispersion, amplitude compression, and spectral shaping to increase the peak/rms ratio of the speech waveform, so that effective broadcast range can be increased subject to the peak power limit of the existing transmitters. Overall, an advantage of about 3 dB has been achieved relative to state-of-the-art commercial devices, with comparable quality for the expected conditions of operational broadcast environments, which represents a doubling of the effective broadcast area. A real-time prototype of the system has been developed and delivered to the Voice of America, implemented in the form of a multiprocessor based on high-performance digital signal processing chips. The prototype provides experimental flexibility through control of the degree of processing and allows on-line monitoring of the peak/rms ratio.

Signal Processor for Space-Based Radar

As part of the Space Radar Technology program, digital signal processing algorithms and real-time processor hardware are being developed in the Sensor Processor Technology Group to demonstrate the processing required for on-board detection and tracking of targets from a spaceborne radar. An orbiting radar must be capable of suppressing high levels of ground and sea clutter, as well as interference from multiple locations on the ground. The signal processor will incorporate special algorithms for simultaneous cancellation of clutter and jammer signals, in addition to conventional algorithms for Doppler filtering and CFAR detection. The three major subsystems comprising the digital signal processor under development are the front-end filter for signal conditioning, the adaptive processor for cancellation of interference, and a programmable vector processor for implementing Doppler filtering and target detection. The completed system will contain approximately 2000 ICs, dissipate 250 Watts, and perform in excess of 12 billion arithmetic operations per second on data which arrives at the rate of 54 million bits per second.

Neural Networks

Applications of neural networks (NN) are being pursued in the domains of speech recognition, object recognition from imagery data, and complex decision problems. In addition, techniques for efficient implementation of neural networks in silicon are being investigated.

In the speech recognition area, research has been initiated on integrating neural nets with Hidden Markov Model (HMM) speech recognizers to take best advantage of the discrimination capability of NN classifiers and the dynamic pattern matching of HMM. In one approach, a neural net used as a post-processor to an HMM recognizer significantly reduced error rate for a limited task, including phonetic distinctions. In a second approach, a hybrid HMM/NN system is being developed wherein the NN functions as an automatically-trainable extractor of acoustic/phonetic features. Modification of HMM training techniques were developed to integrate the NN training without requiring hand segmentation of the speech. Also, the practical characteristics of a variety of NN algorithms for application to speech and pattern classification have been quantified, revealing much similarity in error rate but significant differences in memory requirements, training and recognition time, and ease of adaptivity.

In the object recognition area, the initial emphasis has been on 2-D imagery data. In this regard, a novel network has been developed, called the Neural Analog Diffusion-Enhancement Layer (NADEL) network, consisting of two coupled layers of neural elements that operate on a feature map. The first layer diffuses the feature map as a function of time, while the second layer detects local maxima of activity, contrast enhances them, and feeds back these maxima to the first layer. Besides being able to detect such primitive features as corners and high curvature points in boundaries and line-ends, the NADEL also generates an attractive force that causes distant features to group as time progresses. Feature grouping progresses on multiple scales, with small clusters emerging before extended clusters. Clusters ultimately merge into a single maximum of activity at the centroid of the object feature map. In extending the 2-D system to recognize 3-D objects, the NADEL network is used for feature extraction and clustering, and feature centroid determination.

In the implementation arena, a dynamic analog synapse has been developed and a prototype fabricated, which stores connection strengths as charges on capacitors. The charge establishes a voltage on the gate of a multiplying transistor, whose source is connected to an input voltage and whose drain is connected to a current accumulation bus connected to a virtual ground. Like a dynamic RAM, the charge needs to be refreshed periodically. The ability to refresh the charge was built into a weight adaptation circuit fabricated separately. These two chips have been tested and are undergoing revisions at this time. In addition, work is beginning on a non-volatile charge storage technique using conventional CMOS technology available through MOSIS. This is similar to the dynamic synapse, except that the charge is stored on the gate of the multiplying transistor which is disconnected from any electrical nodes. Circuit techniques are being developed to automatically adjust the charge on the floating gate based on a learning rule.

Rapid Turnaround IC Customization

In the Digital Integrated Circuits Group, techniques for laser programming the connectivity of integrated circuits are being extended to provide higher performance and density. "Same day" customization of complex digital circuits is achieved by forming a pattern of cuts and links in a regular array of universal logic modules comprising 20 transistors, each capable of forming any function of two input variables. Chips with the equivalent of 3000 gates have been fabricated using the DARPA MOSIS foundry service. Cell libraries have been developed for three different commercial schematic capture systems providing ready access for digital designers. Arrays using 2 micron CMOS design rules have been fabricated and programmed, and test arrays using 1.2 micron design rules are to be tested in the near future. Because of the ability to accurately position the laser beam to within a few tenths of a micron, this approach allows area efficiency comparable to that of a channeled gate array while providing the turnaround time of programmable logic devices.

Communications Network Management Technology Demonstration

The worldwide AUTOVON military telephone system is currently being upgraded with modern computer-controlled switches. Robustness and damage resistance improvements are now possible through modern network management practices. The Machine Intelligence Technology Group is developing two remedies to the lack of trained military operators to do this work: a simulation-based Network Management Trainer for the near term, and a Network Management Expert System for the longer term to capture and retain expert knowledge that is being accumulated through experimentation with the Trainer.

The technology of both systems is being transferred to the U.S. European Theater Communications Center in Stuttgart, Germany, where they will be demonstrated in September 1989. They will remain at Stuttgart to support daily operations as well as to test successive new versions developed by Lincoln.

Adaptive Optics Technology

The Lincoln Laboratory program in adaptive optics addresses atmospheric compensation for ground-to-space laser propagation. Both low- and high-power lasers are being studied and thus both turbulence effects and thermal blooming must be compensated.

A major accomplishment in 1989 was the construction and operation of a new wavefront sensor based on CCD detectors and binary-optics lenslet arrays, both of which are built in house. The new sensor permits operation with almost-perfect quantum efficiency and with extremely low readout noise. This sensor is now installed in our Maui field site and is being used in experiments in imaging astronomical sources.

In our laboratory experiments we are investigating the correctability of strong thermal blooming in atmospheric propagation. (Thermal blooming is a spreading of a laser beam which results from a certain amount of the laser power being absorbed by the propagation medium.) Analysis indicates that above a threshold of power density, atmospheric compensation techniques

develop a closed-loop instability which may or may not be manageable. The laboratory experiment is aimed at determining the threshold for the instability which as yet has not been observed.

Satellite Laser Communications

Work in this area has focused on developing high-power (approximately 1 watt) semiconductor laser transmitters for use in coherent communication systems. The availability of high-power sources will allow for significant reduction in aperture size and/or increase in data rate over the current generation of space laser communication systems. Two approaches toward obtaining higher power are being investigated. These approaches are injection locking and non-linear beam combining.

Recent advances in semiconductor laser technology now permit output power in excess of 1 W to be generated by commercially available devices. However, these devices typically operate in multiple spatial and spectral modes, making them unsuitable for coherent communication systems. We have been pursuing an injection locking technique wherein the light from a low-power master oscillator laser is injected into the high-power device forcing it to operate in a single spatio-temporal mode. Recently, over 300 mW of injection locked output has been obtained and used in a coherent communication system demonstration.

Photorefractive two-beam coupling is a non-linear process that allows energy from one laser beam to be preferentially transferred into another. This transfer is relatively independent of the alignment and phasefront differences of the beams. As such, two-beam coupling provides a possible mechanism for combining laser outputs in a robust fashion. Experimental results demonstrating very efficient combining of two injection-locked 30 mW GaAlAs lasers have been obtained. The process is scalable to many lasers.

Low-Temperature GaAs Buffer Layer

GaAs has a greater carrier mobility than Si and is therefore better suited for microwave and high-speed circuit applications. However, GaAs technology has proved to be difficult to implement, partly because there is not available the equivalent of the SiO₂ insulating layer that is used in Si technology. We have demonstrated a new insulating layer of high dielectric strength with crystalline lattice parameters matched to GaAs. The layer, consisting of As-rich GaAs, is grown by molecular beam epitaxy at 200°C, a temperature well below the 600°C normally used for growing device-quality GaAs. The new low-temperature buffer layer can be inserted epitaxially between semiconducting layers to electrically isolate one from the other.

For example, GaAs ICs are typically made on semi-insulating substrates, which have high, but finite resistance. Leakage currents flow through the substrate in response to dc potentials, interfering with the proper functioning of the ICs. Therefore active devices have to be separated sufficiently to minimize this undesirable interaction, which results in a GaAs circuit density significantly less than that of Si. We have demonstrated the elimination of such leakage currents by inserting the low-temperature buffer layer between the active circuits and the

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semi-insulating substrate. Our low-temperature GaAs buffer layer technology is now being adopted by several U.S. laboratories.

CCD Imager Technology

Charge-coupled device (CCD) imagers are under development at Lincoln Laboratory for use in large area, high resolution, low-light level imaging for ground and space surveillance and for use in high frame rate, high-sensitivity cameras for wavefront measurements in adaptive optics experiments. Recent improvements in fabrication and circuit design have led to devices with noise levels of 1.7 electrons rms at 50 kHz clock rates, the lowest noise ever reported. In the past year we have developed techniques to improve the quantum efficiency of the imager and to extend its spectral range into the UV by chemically removing most of the device substrate and illuminating the imager from the back rather than through the gate structure on the front. The finished device is only about 10 micrometers thick, and for structural support is epoxied to a glass substrate with the circuit side of the imager face down. However, good sensitivity in the UV requires special treatment of the etched surface to deflect the photoelectrons toward the CCD wells. To this end, we have successfully created shallow doped layers on the back surface by laser annealing of implanted dopants without adverse effects to the epoxy. Devices built with this technology show good quantum efficiency in the visible and near UV and the promise of extension into the vacuum UV. Using these devices, we have constructed high frame rate cameras that provide the sensitivity required for the wavefront measurement.

In a collaborative effort with the Center for Space Research (CSR) at MIT, the imagers have been evaluated as X-ray sensors for use in future space-based observatories such as ASTRO-D and AXAF. Because of the near-perfect charge transfer efficiency and low noise, these devices have produced the best reported X-ray energy resolution over the range from 0.3 to 10 keV. Focal plane arrays consisting of several closely spaced chips will be made for CSRE for the ASTRO-D mission to be launched in 1993 and for AXAF later in the decade. The back-illuminated technology for UV imaging will also be of considerable interest for X-ray imaging because it will extend the low energy cutoff to 0.1 keV or below.

Space-Based Visible Sensor

Lincoln Laboratory has been engaged in the development of technology and techniques leading to the potential deployment of space-based visible band sensors for space surveillance. These sensors would add significant capability to the current space surveillance network. The concepts being pursued require modest optics and employ advanced CCD focal plane and signal processing technology to provide the requisite performance. The CCD focal planes are made from high sensitivity, high pixel density CCD detector chips fabricated at Lincoln Laboratory. These chips are the best current available for low background applications. The signal processor is designed to provide autonomous star rejection and target detection in a fault tolerant architecture appropriate for space application.

In order to demonstrate this technology in space, Lincoln Laboratory has initiated the development of a visible sensor package which will be flown on the Midcourse Space Experiment satellite to be launched in 1992.

Project Athena

Project Athena

Project Athena is a major initiative undertaken in May, 1983 to explore the potential of a network of high performance, graphics workstations for improving the effectiveness of the MIT curriculum. Funded by major commitments of hardware, maintenance and staff support by Digital Equipment Corporation and IBM as well as financial contributions from diverse corporate and private sponsors, Athena has fostered innovative uses of advanced computing technology over the past six years.

Project Athena has three basic objectives:

1. to support innovations in educational computing use at MIT, with particular emphasis on faculty-initiated projects that use computation in the undergraduate curriculum;
2. to design a "computing environment" that would serve MIT effectively into the 1990's;
3. to implement a large-scale computing system on campus that would support the applications faculty and students created.

In working towards these objectives, Athena has emphasized the use of what has come to be known as "distributed computing", where users rely upon a local computer connected to a high speed communications network. Most computer applications run on the local computer, drawing on an array of computational services provided by remote computers and delivered over the network. This model of computing combines the high computer performance of dedicated, single-user workstations with the capabilities of information sharing that usually characterize multi-user, time-sharing systems.

Athena's major accomplishments towards attaining each of the above objectives are summarized below.

EDUCATIONAL COMPUTING INITIATIVES

During the first five years, Project Athena sponsored 125 curriculum development projects, supporting faculty time, student employees, graduate research assistants and full-time professional programmers. These faculty initiatives spanned all Schools at the Institute and most of their academic departments. Some specific examples include:

- the development of a simulation of the human circulatory system to help students understand the complex dynamics of blood transport and the effects of cardiac malfunction on circulation;
- expert systems developed jointly by the Foreign Languages Section and the Artificial Intelligence Laboratory that allow students to "converse" in any one of five languages;
- a series of modules that are used in the Department of Aeronautics and Astronautics to teach sophomore to senior level students fluid dynamics;

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- a bulletin board system used in Biology to provide an anonymous forum for students to ask faculty and teaching assistants questions without incurring the perceived risk of not understanding material taught in lectures;
- a graphically oriented design tool used in Civil Engineering to provide a hands-on experience in bridge design very early in the curriculum;
- a music laboratory for teaching the structure and organization of music from a procedural perspective;
- a range of undergraduate science and engineering laboratories equipped with digital data acquisition and analysis hardware to expand the range of experimentation and the types of physical phenomena that can be explored experimentally;
- a simulation of a superpower confrontation used in Political Science to help students understand game theory and negotiation;
- a general numerical tool used to generate and analyze thermodynamic problems;
- a computer application that combines video imaging and graphics to teach neuroanatomy students the structure of the human brain;

Some of the Athena-sponsored applications are now being exported to academic institutions outside MIT. This includes the Department Aeronautics and Astronautics' fluid dynamics series (called Todor), the simulation in Political Science (called CASCON), applications to teach special relativity, a program called ASSESS used in teaching decision analysis, and the general laboratory interface system (called the Unkelscope). We expect an increase in export of applications as the software developed by Athena gets further testing and as other universities develop computing systems based on the Athena model.

During the first five years, the curriculum development projects were supported from central funds from Project Athena. During the three year second phase (1988-1991), the central funds are no longer available and faculty must seek departmental, school, or external support.

Many of the most interesting applications are beginning to combine video technology with computation. Athena has created the Visual Computing Group (VCG) to assist faculty in this work and to develop the underlying software tools needed to introduce video into educational applications. Current projects of this group include ongoing work in foreign languages, biology, mechanical engineering, neuroanatomy, film studies, and architecture. The VCG has created a specially-equipped workstation that includes video/graphics controllers, a directly attached videodisk player and a connection to the MIT cable TV system. The software on this workstation includes the entire Athena system with upwards compatible extensions for capturing both moving and still video images.

The Project Athena Study group was established by the Provost's Office in 1985 to foster a series of studies that examine the results of computer use in the educational process. In 1988, a report covering three academic departments (Civil Engineering, Chemistry and Physics) and the School of Architecture and Planning was released. Another study that examines the effects of experimental Athena facilities sited in five MIT living groups was also completed. In addition, Athena has conducted a survey of student computer use patterns each semester, tracking the changes in the amount of Athena and non-Athena computing as the project has expanded over time.

THE ATHENA SYSTEM SOFTWARE

The Athena system has evolved into the campus computing environment used by the majority of MIT undergraduates for their academic computing. All undergraduate students and faculty are automatically eligible for Athena accounts. Graduate students who are teaching assistants, enrolled in subjects using Athena or are part of ongoing curriculum development projects also have Athena access.

The Athena system consists of both workstations and servers. All Athena workstations run the Berkeley 4.3 UNIX operating system enhanced to include: the X Window System (Version 11); a revised set of utilities to make use of Athena's distributed authentication service; the addition of various changes to provide two types of remote file service (Sun's NFS and the MIT Remote Virtual Disk system); and a range of changes to make installation and operation of workstations simpler.

The X Window System was jointly developed by Athena and the Laboratory for Computer Science. An MIT-based consortium with 29 members and 35 affiliates, all committed to provide X as a product on their own hardware, continues to direct the overall architecture and evolution of the X Window System. X has become the industry standard protocol for generation and display of images on bit mapped graphic display devices.

Athena also operates a series of networked-based services, including: file service for system libraries, subject-related materials and private storage; authentication service (called Kerberos); print service; name service (called Hesiod); mail and post office service; dial-in service to connect remote users to Athena via conventional analog telephone lines; and notification service (called Zephyr). We also have developed the Service Management System (called Moira) to maintain and update the approximately 85 server computers we now operate.

Athena has released the Kerberos and Hesoid software outside MIT for beta test. There have been over 100 copies distributed. The high level of industry interest in this software suggests the potential for widespread adoption of these systems in commercially-supported software systems. Other service software is also being requested.

Much of the Athena-developed software was first installed in September, 1987. In the past two years, we have devoted most of our system development efforts towards improving the reliability and performance of that software. We expect to continue these efforts in the coming year as part of the migration of Athena from a experimental system to a campus utility service.

THE PHYSICAL FACILITY

Athena is now the single largest computing system at MIT. Its facilities serve over 7000 regular users at MIT spread out over the entire campus.

As of June, 1989 Athena provided the following resources:

- seventeen public or departmental clusters for general student and faculty use, including a "electronic" classroom;
- five facilities in MIT undergraduate living groups;
- eight development clusters for use by faculty;

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- four projection equipped facilities for lectures requiring presentation of computer generated materials;
- a staff area in Building E40.

These facilities have approximately 900 workstations, 64 printers, and 85 server computers installed as of June 30, 1989. During the past year major efforts were expended to increase the number of printers in response to faculty and student requests. In addition, most of the aging VAX 11/750 file servers were replaced by new technology VAX 3600/3900 and IBM PC/RT file servers. The system reliability increased substantially and the default user quote was doubled to 1.2 mbytes.

Athena usage increased steadily during the year reaching levels approximately 30% greater than the previous year. On the last day of classes 2589 different people used Athena. Approximately 90% of the undergraduates and 30% of the graduate students had Athena accounts. Approximately 100 subjects per semester used Athena for assignments.

Athena also maintains a visitors center staffed with an information officer. Over 2000 people visited Athena during the year to learn about the Athena computing system and the educational initiatives. Presentations were also made by staff and faculty at national and international meetings. Bond University in Australia and Karlsruhe University in Germany have imported the Athena computing system. Inquiries have been received from several other universities.

PLANS FOR THE FUTURE

The major priorities for the next two years will be to:

- improve stability and supportability of Athena software suite;
- develop new funding sources to sustain curriculum development;
- create software tools to improve the human interface to Athena software, reduce cost of application development, and make the system easier to install, operate and maintain;
- provide network services such as mail and printing to "lower end" personal computers;
- expand the base of installed workstations to 1200 - 1500
- extend the video workstation software from its current prototype status to an integral part of the Athena system;
- include graduate and some subset of research computing within Athena model;
- adapt Athena system to make workstations in individual offices and dormitory rooms easier to support;
- encourage private ownership of workstations by faculty and students.

Project Athena is scheduled to conclude in June 1991. During the 1989 AY, a "Committee on Academic Computing for the 1990's and Beyond" was formed. It is chaired by the Dean for Undergraduate Education and consists of 13 faculty members including the

Director of Project Athena and the Vice President for Information Systems, 2 students, and 3 staff members. The committee is charged to "take a comprehensive look at the educational computing needs and possibilities for MIT's undergraduate and graduate students, establish objectives for MIT's educational computing, assess the technology which will be available in the 1990's, consider the costs and management of educational computing at MIT, and recommend options to the Provost" by June 1990.

EARLL M. MURMAN

Associate Provost and Vice President for Research

Francis Bitter National Magnet Laboratory

The Francis Bitter National Magnet Laboratory (FBNML), with support from the National Science Foundation (NSF), operates high magnetic field facilities available, free of charge, to qualified scientists throughout the country. The Laboratory can produce a world record 31.8 tesla (T) in a 33 mm bore, and pulsed fields up to 68 T of duration > 5 ms are available on an experimental basis. The Laboratory also designs and builds magnets, both resistive and superconducting, and performs in-house research in condensed matter physics, condensed matter chemistry, materials science, and biophysics.

Core support for the Laboratory's operations is provided by a cooperative agreement with the NSF, which is subject to peer review and renewal every three years. As a result of the renewal process in 1985, funds for in-house research were eliminated. In the renewal proposal submitted in 1988, we requested funds to resume in-house research, to develop a pulsed field facility, to design a 45 T hybrid magnet, to begin construction of a 750 MHz (17.5 T) NMR magnet, and to replace our 10 MW motor-generator power supply with a 24 MW solid state one. We strongly believe that in-house research is an essential component of a successful national facility, and were pleased that NSF allowed us to resume limited support for appropriate in-house research. Although the present cooperative agreement does not provide sufficient funds for the initiatives we proposed, the first year budget does represent a 20 percent increase over the last year of the previous agreement. Given the well-known budget problems for mathematics and physical sciences at NSF, it indicates the NSF Division of Materials Research is committed to high magnetic field research.

A panel of eminent scientists has advised the NSF that the country needs an upgraded high magnetic field research facility and has spelled out the needed resources. A solicitation for proposals to construct and operate a new national high magnetic field facility was expected from NSF in February 1989, but has not yet been issued. The FBNML intends to respond to the solicitation; at this writing we do not know if the NSF has the resources required to implement the panel's recommendations, or if the Laboratory's bid will be successful. It is disturbing that NSF apparently will require significant cost sharing from the successful bidder; this is a difficult requirement for a private university to meet, and seems especially inappropriate for a national facility.

Although faced with the present uncertain situation, the Laboratory has pressed forward with the resources available to it to operate the existing facilities, to develop new ones, and to carry out research. We outline below some of our accomplishments during the past year.

A major component of the Laboratory's research program is the study of superconductivity. The high critical temperature (T_c) oxide superconductors all have very high estimated critical fields at 4.2 K, and the FBNML is the only facility in the country where the highest fields can be obtained. Consequently, most active programs have made use of FBNML facilities. In-house superconductivity research is carried on by FBNML staff members and by faculty in the departments of Electrical Engineering and Computer Science, Materials Science and Engineering, and Physics. Voltage drop due to flux flow is currently a serious obstacle to the application of the high T_c oxide materials. Experiments performed as part of our in-house research have verified the essential features of a phenomenological model for the resistivity as a function of temperature and magnetic field near T_c . The model is not perfect, but it is a first step towards the better understanding of the process that is essential if flux flow problems are to be overcome. Tunneling studies of superconductors are also an important component of the in-house research program, and our efforts have shown that tunneling through an EuS barrier is sensitive to the spin state of the carriers. This is an important step on the way to achieving our goal of developing a spin polarization sensitive scanning tunneling microscope.

As an example of an exciting development in a user program, we discuss some recent results obtained by a group, from the MIT Center for Materials Science and Engineering, which has been working to elucidate the mechanism for superconductivity in La_2CuO_4 . The Cu^{2+} spins order antiferromagnetically, but are slightly canted to produce a weak ferromagnetic moment in each CuO_2 layer. By using the 20 T fields available at FBNML to study spin flop transitions, the group has been able to show there is a strong antisymmetric exchange coupling between the charge carriers and the magnetic order of the copper spins. They believe this coupling is an important component of the interactions that produce the superconductivity.

The FBNML biomagnetism group has had a successful year. One of the group's projects is to use magnetic field measurements to study the same currents in the brain which produce the electroencephalogram (EEG). However the magnetoencephalogram (MEG) samples the currents differently. The group recently carried out measurements of the MEG due to artificial current sources, of known location, from electrodes implanted in the heads of epilepsy patients; the experiments were successful and will enable refinement of the analysis of MEG measurements. The group has just received an NIH grant to develop a magnetic stimulator for the brain. This

project will make use of technology the laboratory has developed for high field magnet construction, and could lead to a non-invasive method for stimulating electrical activity of the brain.

Nuclear magnetic resonance (NMR) forms a significant part of the Laboratory's in-house research activity; this includes high resolution solid state and liquid state NMR as well as magnetic resonance imaging (MRI). The research on solids uses magic angle spinning (MAS) and deuterium quadrupole echo spectroscopy. The group has developed new MAS techniques to measure internuclear distances in solids. The methods are being applied to structural problems which are not easily investigated by solution techniques. These include determining the structure of inhibitors and large enzymes. The group has found new ways to study the dynamics of polymethylene chains in lipid bilayers, which it will apply to investigate the dynamics of proteins in crystals and membranes. Progress has been made on the construction of a 5.0 T dynamic nuclear polarization (DNP) / NMR double resonance spectrometer. The NMR resonance will be at 210 MHz, while the electron spin resonance occurs at 140 GHz. This requires a gyrotron as a high power microwave source, which is being developed in collaboration with staff at the MIT Plasma Fusion Center. The NIH grant supporting the solution NMR activity was renewed for another five years this spring, and some of the funds requested for the MRI activity were also granted. The MRI group is developing means for active shielding of the gradient coils in the MRI spectrometer, in order to improve the resolution of the images obtained. We were unable to obtain domestic funding for this important work, but are pleased that it will be able to go forward with support from the Toshiba Corporation. The high resolution solution NMR and MRI facilities also are available for medical research in an atmosphere free of the typical clinical pressures of most hospitals.

Magnet-optics using FBNML developed fiber optic systems play an important role in in-house research on dilute magnetic semiconductor (DMS) materials and semiconductor heterostructures. A new program has begun, in collaboration with AT&T Bell Laboratories, to explore many particle electron-electron interactions in restricted spatial dimensions. The recent advances in pulsed field generation, discussed in last year's report, have been applied to study spin clusters in DMS; an unexpected bonus was the discovery that relaxation times in the samples studied were sufficiently long that dynamical information can be obtained using field pulses of about five millisecond length.

In-house research on cryotribology and cryomechanics of conventional (low T_c) superconducting materials has continued and been extended to investigate temperature dependent behavior and wear, lubrication, and fracture of polymeric materials and metals. A program on magnetic refrigeration has been started. The initial goal is to produce and study a small magnetic refrigerator to produce temperatures in the 1 K to 15 K range. This research is in collaboration with faculty in the Department of Mechanical Engineering.

The Laboratory has also continued with magnet technology and facilities development. Our latest superconducting magnet for NMR has been installed in its cryostat. The magnet has a field of 14.1 T (600 MHz proton NMR), a room temperature bore of 50.8 mm, and a stability of 0.01 ppm per hour. Its construction involved the development of novel technology including hybrid superconducting joints (between niobium-tin and niobium-titanium) and protection against the effects of Lorentz force amplification during quenching in the coupled windings. The magnet is now being shimmed to achieve its target linewidth of 0.1 Hz.

Work on the Cu/Nb-matrix microcomposite wire-wound pulsed magnets, which achieved a world record 68.4 T, has continued. The old capacitor bank with PCB filled capacitors has been replaced with one storing slightly more energy. As mentioned above, the magnets have been used to study DMS materials. It has become clear that improved materials, to get higher strength while maintaining conductivity, can have enormous payoff in the fields attainable; better materials could also greatly reduce the cost of the 45 T DC magnet which the Laboratory eventually hopes to build. We intend to devote much of our effort to materials development during the coming year.

Construction of our next hybrid magnet, designed to work with a superconducting background field of 13 T and to produce a total field in excess of 35 T, continues. The high field superconducting winding has been completed and winding of the the lower field coil is in progress. A contract to produce the monohelix resistive insert has been signed with Toshiba. The project is scheduled for completion in 1990.

During the coming year we expect to replace the aging DEC MINC computers used for data acquisition in the high field magnets with Macintosh II machines running the Labview software package available from National Instruments. This reflects the Laboratory's policy of providing the best possible service to our users that is consistent with the resources available to us.

J. DAVID LITSTER

Center for Cognitive Science

INTRODUCTION

During the academic year 1988-89, the Center for Cognitive Science continued to foster interdisciplinary research in human cognition, primarily through development of the Computational Laboratory and the various programs outlined below. These activities were coordinated through the Center's Working Group, which reviews all proposals by means of a committee structure and approves expenditures for those programs judged worthy of support.

Computational Laboratory

Since 1981, the Computational Laboratory of the Center for Cognitive Science has provided the cognitive science community at MIT with computational facilities for data analysis, simulation, stimulus preparation, linguistic analysis, and on-line control of experiments on perception, cognition, and language. The Laboratory is the principal experimental research facility for graduate students and faculty in linguistics and in human experimental psychology and serves the visiting scientists and postdoctoral fellows in residence at the Center and in the Department of Brain and Cognitive Sciences each year. In addition, undergraduates taking Subject 9.63, "Laboratory in Cognitive Science", use it to carry out their weekly lab assignments.

There are two concentrations of equipment, one in Building 20, primarily serving Center members from the Department of Linguistics and Philosophy and visitors to the Center, the other in Building E10, primarily serving members from the Department of Brain and Cognitive Sciences. The facility in 20C-231 contains a Microvax II running DEC ULTRIX, which is used to train graduate students in LISP-based simulations of human sentence parsing, to maintain the on-line dictionaries created by the Lexicon Project, to format and laser-print technical manuscripts in linguistics and logic, to simulate human reasoning, and for electronic mail.

In addition, the Building 20 facility has several subject testing stations used for experiments in cognitive psychology and psycholinguistics. They consist of IBM AT microcomputers dedicated to process control and data acquisition in real-time, connected to video monitors, headphones, slide projectors, tape recorders, response switches, and eye-movement recording equipment. Over the past several years the Laboratory developed a software system for on-line control of experiments that insulates the user from idiosyncrasies of the hardware interface to lab peripherals. An experimenter who is totally unfamiliar with programming can use this system to create customized programs for implementing novel experimental paradigms.

The facilities in E10, purchased in part with funds from the Fairchild Foundation, Project Athena, and individual NSF grants, consist of another Microvax II and 6 IBM AT or XT microcomputers used for experimental research. The Microvax is used for electronic mail, simulation, statistical analysis, and manipulation of on-line databases of children's and aphasics' speech.

There have been two major new developments in 1988-89. A Macintosh II computer has been set up and integrated into the E10 lab, and is used to generate complex stimuli such as three-dimensional shapes and human faces, which can then be presented to subjects in real time on the experimental workstations. In addition, two different networks of Sun workstations and file servers are being installed, one in Building 20 for use in the Parsing Project (see below), and one in Building E10 for use in the simulation of human

planning of action and human conceptual reasoning. These machines are necessary to allow students and researchers to develop highly parallel, computation-intensive simulations that are becoming increasingly important in the modeling of language and cognition.

RESEARCH

The Parsing Project

During the past year, the Parsing Project continued its successful seminar series of invited speakers. An edited volume of last year's seminars was published under the auspices of the Cognitive Science Center, and plans are underway to do the same with the second year's seminars.

The computational facilities for the project have been nearly completed. Several Macintoshes provide a hardware platform for personal Lisp workstations, while Cogito acts as a fileserver. During the past year, the Project acquired a large, million-word English corpus to serve as a testbed for various hypotheses about lexical semantics. A general-purpose morphological front end parser was completed, as well as a statistically-based lexical disambiguator. These components will serve as tool-kit "blackboxes" that can be used in every future parser design.

The Lexicon Project

The major ongoing research project in the Center during the past year has been the Lexicon Project. The work being done in this project has two aspects, one descriptive, the other theoretical. Descriptively, the Project is collecting and documenting the lexical resources of three Non-Indo-European languages, namely: Tamazight Berber (Morocco), Warlpiri (Central Australia), and Winnebago (Wisconsin). Theoretically, the Project is involved in the general effort within theoretical linguistics to deepen understanding of the lexicon, a topic of crucial importance in understanding human language abilities. English and other well-known languages figure prominently as objects of this research, as do the Non-Indo-European languages mentioned above. This work is, therefore, largely comparative and seeks to elaborate a general theory of the lexicon and its relation to other components of grammar.

During the four years of the Project, work has continued on the implementation of a framework that will allow us to build a computer-based database for English verbs. This database will contain information about the properties of verbs that will form a foundation for further work on lexical semantics and the construction of a lexicon complementing the work on parsing being done at MIT. As part of this effort, the Lexicon Project is compiling a set of resource materials on English lexical organization, focusing on verb classification and diathesis alternations, which will be put out in the Lexicon Project Working Papers series.

The Visitor Selection Committee

During the academic year 1988-89 the Center sponsored five visiting scientists.

The Affiliate Program

The Center continued its affiliate program, which provides formal status for individuals who are connected with Center research but are not in residence at MIT. Affiliates are individuals who are working actively in the field and observers of the field who wish to have an affiliation with the Center.

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The Member Program

The Center maintained its Member program, which provides individuals within the MIT community with formal affiliation. The program was designed for individuals whose interests significantly overlap with, and support the intellectual goals of the Center. At present there are seven designated Members of the Center: Professor Kenneth Hale of the Department of Linguistics and Philosophy, Professors Emilio Bizzi, Whitman Richards and Jeremy Wolfe of the Department of Brain and Cognitive Sciences, Professor Suzanne Flynn of Foreign Languages and Literature, Dr. Stefanie Shattuck-Hufnagel of the Research Laboratory of Electronics and Dr. Lucia Vaina of Health Sciences.

Seminars and Colloquia

During the 1988-89 academic year the Center continued to support four kinds of seminars. The Center for Cognitive Science Seminar Series, a monthly seminar, is open to the community at large and presents papers on a variety of topics relevant to the Center. The papers are distributed to seminar participants before the meeting. At the seminar itself, a commentator or commentators present the paper. The author follows with comments and the paper is then open for general discussion from the floor. During the past decade a number of seminal papers in cognitive science received their first public airing in this forum, which has attracted an audience from all over the Northeast. Last year, in particular, over 750 members of the community attended a total of 9 seminars. Second, the Lexicon Project conducts fortnightly meetings on topics about the structure of the lexicon. These meetings are attended by approximately 200 scholars from a number of MIT departments and other institutions in the area. Third, the Center has initiated the Parsing Project seminar, attended on a fortnightly basis by scholars from MIT and other institutions. The fourth seminar is the Philosophy and Psychology discussion group, consisting of philosophers and psychologists from MIT, Harvard, and Tufts who meet on a monthly basis to explore topics of common interest.

The Occasional Paper Program

The Center for Cognitive Science sponsors a series of Occasional Papers. The papers are designed to inform fellow workers in the field of the current research undertaken at the Center. To date thirty-seven Occasional Papers have been published, a number of which are authored by visitors to the Center and represent work accomplished during their stay.

The Lexicon Project Working Papers

Lexicon Project Working Papers are sponsored by the Center. These papers describe the work carried out at the Center in conjunction with the Lexicon Project. The aim of these papers is to report current research on the Lexicon Project. To date, thirty-one papers have been published.

The Parsing Project Working Papers

The Parsing Project has begun its own working paper series, the first volume of which is a collection of articles on various aspects of sentence parsing and recognition. These articles are drawn from the Parsing Project seminar talks held during 1988-89.

Publications

The Center for Cognitive Science has supported a variety of publications by making its resources available to visiting scientists and affiliated faculty. As of the end of the academic year 1988-89, a total of 19 books and 208 articles had been published in part with Center support.

SAMUEL JAY KEYSER

Center for Materials Science and Engineering

Materials figure prominently in many areas of science and technology. The unavailability of substances which possess required properties or perfection often forms the main obstacle in the development of a new system, process, or device. Conversely, the discovery of a new property or class of materials (oxide superconductors being a recent example) may generate new industries. An understanding of the relation between structure, composition, and properties of materials is, therefore, essential to future technological development as well as being a subject of continuing scientific and intellectual challenge in its own right.

This remains as true today as it was in 1960 when the Advanced Research Projects Agency established a system of Interdisciplinary Laboratories (IDL's) at selected universities. The IDL's were founded in the belief 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. Moreover, if progress were to be made on many critical materials problems, it would be necessary to organize interdisciplinary collaborations which involved viewpoints and backgrounds drawn from many traditional departments of science and engineering. There are few workers in materials-related areas who would disagree with the sentiment today. It should be recalled, however, that the notion of a "materials science" as an identifiable discipline in which a common concern with structure-property-processing relations transcends the boundaries between the traditional classes of materials had begun to emerge only in the late 1950's. Support for the IDL's was assumed by the National Science Foundation (NSF) in July 1972 under the Materials Research Laboratories Program (MRL) of the Division of Materials Research (DMR). Shortly thereafter, NSF issued a policy statement which defined policy for the transition period and which outlined a general philosophy in justification of the substantial block funding committed to the MRL program. This philosophy continues to be followed at present. The support was to include funding for coordinated multi-investigator projects in "major thrust areas" (thus defining a terminology used in this and earlier reports) and seed money for support of junior faculty or established faculty who were changing fields to an area of relevance to a thrust. Programs of this sort were viewed as difficult or unfeasible under the traditional single-investigator mode of NSF support. In addition, support was to be included for the establishment and operation of major central research facilities. Each MRL was given significant local autonomy in planning and managing its programs as a means to maximize the effectiveness of the block-funding approach. A consequence of this unique autonomy is the ability to act quickly on new research opportunities and to utilize effectively faculty and institutional resources.

The MRL program remained static for the first ten years of its existence. Only small annual increases were made to the budget of the program, and it was impossible to start a new MRL. That situation continued until six years ago when, after major review, NSF pruned the existing MRL's from 14 to the present group of nine. The action allowed adequate support under the constraints of a previously inadequate budget for those laboratories deemed to be operating successful, productive programs. Budgetary limitations have continued to the period of the present report and have impeded the establishment of programs in emerging areas that we view as important. Two years ago, upon submission of the proposal to NSF to renew the three-year funding cycle, the initiation of research in a new thrust area on processing of artificially-structured thin films was proposed. The project was not approved for funding, but resubmission was encouraged rather than tabling any activity for three years until the start of the subsequent grant cycle. Several research efforts were established as seed programs during the present year so that we could begin work in this area. A reorganized and more tightly integrated program on atomic mechanisms in heteroepitaxial films was proposed for supplemental funding beginning in March 1989. The program was strong and peer reviews reflected its quality. Unfortunately, the 17 percent budget increase requested by NSF was reduced by the Congress to 10 percent. When programs mandated by Congress in the appropriations bill were funded and an NSF commitment to the newly-proposed Science and Technology Centers was fulfilled, a four percent budget increase was passed down to DMR and the MRL Program was continued at level funding. Funding for the initiative in thin films, not surprisingly, was not approved. Any increase in our program would have had to have been at the expense of our sister laboratories in the MRL Program. It was, therefore, necessary to make difficult decisions on phasing out or terminating many of the seed projects on thin films processing and characterization which had been initiated in order to get a head start on this anticipated Area of Thrust. Although painful, such action was necessary to preserve sufficient latitude to permit consideration of support for a small number of newly-submitted seed proposals. We consider the material science and processing of thin films to be important, however, and some projects have been continued in this emerging field.

During the year just concluded, CMSE supported research in five Areas of Thrust centered on themes which ranged from the fundamental science of phase transitions to groups of investigators with engineering focus such as the mechanical properties of intermetallic compounds having real potential for application in advanced gas turbine engines. A general description of research in each of the five Areas of Thrust, along with the names and department affiliation of the principal investigators, is presented in the following sections. Only one or two highlights are presented from the research progress of the past year. Description of each individual project is contained in *Research in Materials Annual Report*, which is compiled and published by CMSE on behalf of MIT.

Fifteen seed projects were funded in 1988-89. The principal investigators of nine projects were junior members of the faculty (five of the six remaining awards to senior faculty were related to the proposed thin-films thrust). In aggregate, CMSE supported thrust area and seed projects for 39 principal investigators drawn from eight different academic departments—one-third of the departments which exist at MIT. The direct funding of research projects by CMSE through NSF/MRL support represents on the order of about fifteen percent of the research in materials at MIT. CMSE provides further support, however, through the establishment and operation of central facilities. These laboratories often involve state-of-the-art and sometimes unique apparatus that is too expensive to be acquired and maintained by an individual research group. The central facilities are available to the entire MIT community (and to sister institutions when capacity is available to accommodate their work) for modest user fees which permit partial recovery of costs. Through such subsidies, the CMSE program has influence that extends beyond the research which it is able to support directly. Such leverage pleases our NSF sponsors. CMSE operated thirteen central facilities during 1988-89 which ranged from a machine shop to a multi-instrument transmission electron microscopy laboratory, from a facility for crystal growth to a laboratory for sophisticated surface analysis. Recent modifications and additions to apparatus are highlighted below.

The research which is conducted within CMSE provides exceptional opportunities for interdisciplinary training of undergraduate as well as graduate students. During 1988-89 CMSE provided support for 26 semesters of UROP activity for 17 students enrolled in 7 different academic departments. On average, there was one UROP project for every three principal investigators. The thrust area devoted to oxide superconductors was an exception. The excitement and interest associated with this research was contagious to undergraduates as well, and UROP participation was three times higher than the level of involvement cited for our other research efforts. We are pleased with one measure of the extent to which CMSE appears to have fostered interdisciplinary interactions: 18 percent of the UROP projects were performed with members of the faculty with affiliations outside the student's home department.

The Center, through its central facilities, presented a number of minicourses and Independent Activity Programs designed to introduce students to the capabilities and operation of the instruments that they house and maintain. The Center also ran a weekly colloquium series, held usually at Friday noon. Many of the presentations during 1988-89 were reports on research at the forefront of activity on high critical-temperature superconducting oxides. The colloquium series was highly successful because of the rapid pace and widespread interest in these materials. Standing room only was the rule, rather than the exception. CMSE also provided support, jointly with the Department of Physics and the Research Laboratory for Electronics, for a condensed-matter seminar series. The Center also provides focus and showcase for the full range of materials research performed at MIT by assuming the responsibility for coordinating, assembling and publishing interdepartmental annual reports which subsequently receive wide distribution. Among these are *Research in Materials* (ca. 450 pages) and *Polymer Research Annual Report* (ca. 100 pages).

Faculty directly contribute to the administration of CMSE in two ways. Each central facility has a faculty supervisor as well as a laboratory manager. (The latter individuals usually hold staff appointments through CMSE. Sometimes, largely for historical reasons, these individuals are appointed through academic departments, but CMSE provides all or a portion of their salaries.) Secondly, all changes in CMSE policy and approvals of seed proposals, equipment requests, and space changes are made after discussion and recommended action proposed by an Internal Advisory Committee. This group consists of the faculty members who serve as leaders of the thrust area research groups plus several additional faculty members-at-large selected to insure balanced representation from the departments that are involved in CMSE programs and, further, to insure representation from key central research facilities.

PERSONNEL CHANGES

Sweeping changes in administrative staff occurred during 1988-89. The previous Director, Professor J. David Litster of the Department of Physics, resigned effective June 30, 1988, to become Director of the Francis Bitter National Magnet Laboratory (FBNML). He was succeeded as CMSE Director by Professor Bernhardt J. Wuensch of the Department of Materials Science and Engineering as of July 1, 1988. Also appointed at that time was Susan Rosevear, Senior Editorial Assistant who, among other duties, assumed responsibility for CMSE publications and coordination of the colloquium series.

The previous Administrative Officer of the Center, Deirdre Dow-Chase, and an Administrative Assistant, Kathleen McCue, accompanied Professor Litster in his move to FBNML. However, to assure continuity during the transition, Ms. Dow-Chase retained a part-time affiliation with CMSE, which was gradually phased out over a period that extended to October 1, 1988. Virginia Esau, appointed to CMSE Headquarters in March 1988 as Fiscal Administrator, was promoted to Administrative Officer effective October 1, 1988. The vacancy left by her promotion was ably filled by Ronald Hasseltine, appointed Fiscal Administrator on January 17, 1989.

Changes in the research staff of CMSE included the following promotions and appointments: John Martin, promoted to Research Scientist, and Elizabeth Shaw, promoted to Research Specialist, both as a result of new apparatus and expanded activity in the Central Facility for Surface Analysis; Richard Perilli was promoted to Research Specialist. Arlete Cassanho and Peter Kloumann were appointed Research Scientists in October 1988 and Helena Goldfarb, Senior Technical Staff, transferred from the Department of Physics in August 1988. Wu-Xian Wang resigned as Research Specialist in the Rapid Solidification Laboratory to return to Shanghai, China, and was replaced by Song-Chun Li.

CURRENT RESEARCH

We present in the following a brief description of the general nature, faculty participants and their departmental affiliation for each of the research areas.

Transition Metal Oxides

This is the newest, but also the largest, thrust area and was initiated shortly after the discovery of superconductivity in rare earth-copper oxides. An early achievement of this thrust was the successful growth of the first large single crystals of La_2CuO_4 by top-seeded growth from a flux. These crystals were of sufficient size to permit neutron scattering studies of the soft-mode nature of the tetragonal to orthorhombic phase transition in the material. The material becomes superconducting when doped by Ba or Sr solutes at a level which causes a sufficiently large concentration of charge-carrying holes. Magnetoresistance studies revealed a very strong coupling between anti-ferromagnetic ordering and the carriers. Neutron scattering measurements showed that the holes disrupt the phase coherence of the magnetic correlations while leaving unchanged the unusually large magnitude of the correlation length for the interaction. A basic feature of this type of superconductor is a spin system which is rapidly fluctuating and strongly coupled to the charge carriers.

Quite recently, new superconducting oxide materials have been discovered which are non-magnetic and yet others in which the charge of the cation added in solid solution creates electrons rather than holes. During 1988-89 strong efforts have been made to produce large-single crystals of these materials as well, and comparable success has been achieved. Top-seeded solution growth has produced large crystals of Ce-doped Nd_2CuO_4 (2 cm x 2 cm x 1 mm), Pr_2CuO_4 (2 cm x 2 cm x 2 mm) and Ce-doped La_2CuO_4 . The synergism between the production of high quality single crystals of these materials, studies of structure and properties, and theory of the origin of the superconducting behavior will continue for these newer families of materials.

The activities of the thrust also encompass studies of defects, processing, and devices. One procedure developed for practical production of these materials is based upon rapid solidification of a mixture of the component metals with a noble metal such as silver, platinum, or gold. Oxidation of the mixture produces a composite of the superconducting oxide and the noble metal which helps overcome the brittleness of these ceramics. This new process has resulted in the issuing to MIT of the first patent in the nation granted for processing of oxide superconductors. In other related

work, advanced electron microscopes with resolution sufficient to allow one to see the individual atoms in a crystalline lattice have resulted in the discovery of a new family of superconducting oxides. One of the most-studied oxide superconductors has been $\text{ReBa}_2\text{Cu}_3\text{O}_{7-x}$, where Re is a rare earth element such as Y, Eu or Yb. This phase is commonly referred to, for short, as the "1-2-3" compound on the basis of the relative numbers of the cations in its composition. High-resolution microscopy has revealed a homologous series of structures $\text{Re}_n\text{Ba}_n\text{Cu}_{3n+1}\text{O}_y$ of which 1-2-3 is the phase with $n = 1$. Work in the thrust has resulted in the discovery of phases in which $n = 2, 3, 4$. Specimens have been produced which consisted of 90 percent or more of the phase 2-4-7 which corresponds to $n = 2$. The phase has a critical temperature (resistance of zero) of 85 K, about 5 K lower than 1-2-3, but has a much more platy shape to the grains which lends itself to texturing for improvement of the magnitude of the critical current. Indeed, the 2-4-7 material can support critical currents which have been found to be two to three times larger than those for 1-2-3 formed in similar fashion.

The DC superconducting quantum interference device (SQUID) is an extremely sensitive detector of magnetic fields, and will likely be one of the first devices in which superconducting oxides see commercial application. Although several groups have fabricated SQUIDS from the 1-2-3 superconductors or the more recently discovered materials in the system Tl-Ba-Ca-Cu-O, we know of no device fabricated from the $T_c = 110$ K phase $\text{Bi}_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10-x}$. A group of faculty from the Departments of Physics, Electrical Engineering and Computer Science, and Materials Science and Engineering have collaborated to produce the first known SQUID fabricated from the material. Large grain (10-20 μm) polycrystalline thin films with T_c ($R = 0$) greater than 100 K were produced by reactive magnetron sputtering and patterned by photolithography. The device so produced was operated at temperatures up to 75 K and displayed a flux noise which was within a factor of 20 of the lowest noise reported to date for SQUIDS fabricated for the Tl-based high T_c materials.

Participating faculty and departmental affiliation: Professors R. J. Birgeneau, M. A. Kastner, P. A. Lee (Physics); M. S. Dresselhaus, T. P. Orlando (Electrical Engineering and Computer Science); Y.-M. Chiang, D. A. Rudman, H. L. Tuller, J. B. Vander Sande, G. J. Yurek (Materials Science and Engineering); and H. Jenssen (Principal Research Scientist, CMSE).

Phases and Phase Transitions

Research in this thrust area involves collaborations among faculty drawn from the Departments of Chemistry, Physics, and Nuclear Engineering in experimental and theoretical work designed to understand the basic nature of phase transformations in condensed matter. The experimental tools and materials studied cover a wide range. Neutron and light-scattering have been used to test theoretical models and determine the structure of micelles, microemulsions, and colloids. High resolution x-ray scattering and light scattering have been used in elegant studies of free-standing liquid crystal films which are sufficiently thin (several molecules!) that they display a crossover from three-dimensional behavior to that of the two-dimensional solids which have been the subject of extensive theoretical analysis.

Participating faculty and departmental affiliation: Professors C. W. Garland (Chemistry); G. B. Benedek, A. N. Berker, R. J. Birgeneau, J. D. Litster, T. Tanaka (Physics); and S.-H. Chen (Nuclear Engineering).

Synthesis and Properties of Novel Polymers

The research in this thrust area consists of a coordinated effort among faculty from four departments directed towards the synthesis of novel polymers and investigation of the electrical and mechanical behavior of polymers. Transition metal catalysts are employed which will specifically attack carbon-carbon double or triple bonds in cyclic molecules, but not the ordinary double or triple bonds in the resulting polymer, providing diblock and triblock polymers of varying length. Such conjugated systems have interesting optical and electronic properties. Doping may result in conducting polymer films or composite microstructures (for example conductive spheres in a host matrix) which should display high dielectric constants. Films of conjugated polymers such as polypyrrole and polyaniline may be doped so that they conduct only in a limited range of applied voltage. Theoretical studies on these and related materials have been conducted in attempts to explain the effect of changes in molecular electronic structure on optical and conduction properties. Other collaborations are directed towards understanding mechanisms of plastic deformation and toughening mechanisms in semicrystalline polymers.

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Participating faculty and departmental affiliation: Professors R. R. Schrock, R. J. Silbey, M. S. Wrighton (Chemistry); R. E. Cohen (Chemical Engineering); M. F. Rubner (Materials Science and Engineering); and A. S. Argon (Mechanical Engineering).

Intermetallic Compounds at High Temperature

Members of this thrust area are drawn from the Departments of Mechanical Engineering and from Materials Science and Engineering. The focus is on generic mechanisms of deformation and damage resistance at high temperatures in advanced alloys and intermetallic compounds which have realistic potential for application in engines. Little prior attention has been given to generic mechanisms at high temperatures where concurrent microstructural alterations are rapid. Remarkable and uninterrupted improvements in the limits on operating stress and temperature limitations have occurred in the last several decades. But, whenever a better material is developed or more confidence is placed in its use, it is pushed to its limits, so that there is always a materials-limited problem in performance.

Prediction of the mechanical behavior of materials and their durability is of primary concern to the engineer. Lifetime predictions were, in the past, necessarily simple and approximate, based typically on monotonic creep deformation or regular cyclic fatigue cracking. During 1988-89 one project achieved considerable success in modeling material response to the aperiodic thermo-mechanical loadings which constitute a service cycle of a typical aircraft flight. The research concerned the intermediate temperatures (900-1250 K) and cyclic strain-time histories (strain 0.3 to 1.0 percent) encountered at the leading and trailing edges of cooled gas turbine blades. In searching for evolutionary equations, one would like to obtain necessary information rapidly from small specimens and with fabrication of a minimum number of specimens. It proved possible to achieve these goals, when working with small deformations, by establishing a quasi-steady reference state of cycling. The effect of temperature or strain rate may be studied by imposing incremental changes on that cycle. In a study of INCONEL 718 at 850° C it has been found that increments of change in strain rates or temperature (which themselves are of interest as representing realistic excursions from a cyclic state of a sort that will be experienced in actual service) are transients from which the quasi-steady state is rapidly recovered.

Participating faculty and departmental affiliation: Professors S. M. Allen, R. M. N. Pelloux (Materials Science and Engineering); A. S. Argon, L. Anand, F. A. McClintock and D. M. Parks (Mechanical Engineering).

Innovations in Steel Technology

A fifth Area of Thrust represented a unique collaboration which involved, in addition to CMSE, the MRL at Harvard University, a Materials Research Group at Brown University, and several laboratories in government and industry. The collaboration was founded on the belief that microstructure-property relations in steels were sufficiently well established that it should be possible to design, from first principles, martensitic steels of improved hardness and ferrite-based alloys with higher flow strength. Progress was indeed made in developing a very high-strength steel. Work would have continued at CMSE were it not for the fact that the thrust-area leader, who had brought the participants together and made the program work, resigned from MIT to assume a faculty position at another university. At the start of the present three-year funding cycle, it was decided that the leadership of the consortium should move with him. The NSF/MRL Program provided a final period of funding to permit four graduate students, who were completing doctoral theses, to conclude their work in timely and adequately-supported fashion. This research has been completed and the thrust area was phased out in February 1989.

Participating faculty and departmental affiliation: S. M. Allen (Materials Science and Engineering).

Seed Research

Seed research projects, reviewed on a yearly basis, are conducted on a very wide range of topics. Such projects support the ideas of recently appointed junior faculty members or are projects initiated with the expectation that they may be eventually incorporated into one of the Areas of Thrust. On occasion, support may be provided for a feasibility study or for a novel idea of great interest and promise, but which involves some risk; such proposals are unlikely to fare well at the hands of formal, outside peer review.

During 1988-89, two investigations initiated under seed support were incorporated into thrust areas—one into the polymer program, the second into the thrust area concerned with superconducting oxides. A new seed project was approved for the growth of single crystals of intermetallic compounds with the aid of laser techniques. The materials produced will be of interest to the research concerned with the mechanical behavior of intermetallic compounds. An additional pair of seed projects awarded to junior faculty studies have continued investigation of emulsions and micelles and catalytic synthesis of novel polymers, respectively. These studies are also related to thrust area interests. Five seed projects had been initiated with expectation that funding would be secured for the new thrust area devoted to thin films. When, in February 1989, it was learned that this project would not be funded, two projects were reluctantly discontinued and two were phased out more gradually to permit the completion of graduate thesis research. The fifth, being conducted by a junior faculty member, was continued.

Participating faculty and departmental affiliations: D. Blankschtein (Chemical Engineering); S. L. Buchwald (Chemistry), C. G. Fonstad, T. P. Orlando, L.R. Reif (Electrical Engineering and Computer Science); J. M. Graybeal, T. J. Greytak, M. Kardar, B.G. Kotliar, S. Mochrie (Physics); N. Herbots, L. W. Hobbs, M. F. Rubner, D. A. Rudman, C. V. Thompson (Materials Science and Engineering).

CENTRAL FACILITIES

The following upgrades of equipment and capability of the 13 laboratories operated by CMSE as Central Research Facilities were especially noteworthy. The Polymer Central Facility has placed in operation the 200 MHz spectrometer which it sought, a need kindly filled by IBM. The instrument has seen significant use, one example being a study of radiation-induced cross-linking in a hybrid nylon-polydiacetylene.

The major expansion of our capability for sophisticated surface analysis is now essentially complete. The facility is operated in collaboration with Harvard University. A General Ionex Tanditron Accelerator for Rutherford back-scattering analysis, a Surface Science Labs KEVEX SSX100 x-ray photoemission spectrometer, a Perkin Elmer Model 660 Scanning Auger Microprobe, and a Vacuum Generators Model 1X 70S SIMSLAB for secondary-ion mass spectrometry have all been installed and are operational. The former two instruments reside at Harvard, the latter pair at CMSE. The supervisor of our facility has been working with his counterpart at Harvard to develop a computer system which will link the two laboratories and facilitate accounting and scheduling.

Our Central Facility for Scanning Transmission Electron Microscopy and Transmission Electron Microscopy has been one of our most successful and heavily-used laboratories. The facility contains four TEM instruments, two of which are approaching twenty years of age and are no longer capable of satisfying the requirements of any but an occasional user. Plans are well underway, therefore, to dispose of the two older instruments and replace them with a single up-to-date microscope. This will provide three state-of-the-art instruments well matched to the workload of the facility. Delivery of the new instrument is anticipated in late 1989.

BERNHARDT J. WUENSCH

Division of Comparative Medicine

MIT has assumed a major role in the animal related biomedical sciences and therefore a comprehensive laboratory animal care and use program has been established. The Institute received AAALAC accreditation in 1972 as a result of its persistent program for improving the quality of animal care and management. In 1975, the Institute further identified the need for professional guidance and improved veterinary services by creating a Division of Laboratory Animal Medicine, directed by Dr. James G. Fox. Also, in 1975, a formal diagnostic laboratory, directed by Dr. James C. Murphy, was established in the Division; in 1976, the NIH RADL grant was initially funded.

For the ensuing 14 years, an extensive and successful program to consolidate and modernize the animal care and use program was undertaken. This included instituting centralized management of all animal care activities, recruitment of qualified personnel and implementing a 14 million dollar renovation and new construction program which provided 80,000 square feet of modern animal facilities, including those in the Whitehead Institute that opened in 1984. The MIT AAALAC-approved animal facilities are staffed and supervised by DCM personnel. Each facility holds a variety of separately housed species, and is serviced by its own cage washing unit. Animal rooms are maintained on controlled photo-periods and the temperature and environmental conditions are closely monitored by visual inspection and electronic monitoring devices. All animal enclosures and rooms are maintained and sanitized using appropriate cleaning schedules and disinfectants. All animal care facilities are under the supervision of the Manager of Animal Facilities. He is supported by an Assistant Manager and the Facilities Coordinator. The Facilities Coordinator is responsible for physical and environmental maintenance of the animal facilities. These three people closely coordinate their efforts with those of the veterinary staff. Each animal facility is supervised by an Animal Technologist who has varying numbers of animal technicians working under his supervision. New information regarding animal care and use is relayed to the technicians during weekly meetings with the clinical staff. Changes in husbandry suggested by the clinical staff are approved by the Director and implemented by the Facilities Manager.

In 1980, the Division of Laboratory Animal Medicine was renamed the Division of Comparative Medicine to reflect the growing emphasis on research and teaching in laboratory animal disease and in the area of animal model development. Since 1983, the Division Director has been a member of the Faculty Council. Additional academic staff include Dr. Neil Lipman, Associate Director, Dr. Robert Marini, Chief of Surgical Resources, Dr. Rebecca Rose, Comparative Pathologist, Dr. Charles Seymour, a recently appointed virologist in our Division, and Ms. Nancy Taylor, Supervisor of the DCM research laboratory.

Animal experimentation continues to be a focal point of debate in the City of Cambridge. After three years of heated dialogue and the commissioning of a Blue Ribbon Committee in 1987 charged with investigating whether or not adequate standards for care of laboratory animals exists and whether or not abuse of laboratory animals occurs, the Committee issued its report to the Cambridge City Council in February 1989. As a result of their extensive on site review of animal research laboratories in Cambridge, including MIT, the Committee's report indicated that adequate care existed for laboratory animals and abuse of laboratory animals was not observed. Nevertheless, the Committee made several recommendations which subsequently were drafted into a Cambridge Ordinance in June 1989. The ordinance that was approved by the Council is by far the least controversial of the number of proposed ordinances that were debated and entertained by the Cambridge Council during the last several years. In essence the new ordinance adds another layer of inspection and review of animal care and use programs at MIT. We currently are reviewed on a routine basis by USDA and Massachusetts Department of Public Health as well as the American Association of Accreditation of Laboratory Animal Care. In addition, MIT complies with stringent NIH guidelines regarding animal care and use programs. The ordinance establishes an independent Commissioner of Laboratory Animals (CLA) who will inspect local facilities to ensure compliance. The ordinance also extends NIH guidelines and Animal Welfare Act legislative mandates to cover all Cambridge research institutions using animals, including those using only mice and/or rats. It also requires that all institutions designate animal care committees with an unaffiliated member to be appointed by the Chief Executive Officer and approved by the CLA. Unlike earlier proposed ordinances, the approved ordinance doesn't give Cambridge the responsibility to review or approve research. The ordinance also abides by the Animal Welfare Act's requirement for a non-affiliated individual to be a member of the institution's Animal Care and Use Committee whose appointment is made by the CEO of the institution.

The NIH-funded diagnostic laboratory has been an integral component of the Division's development and has made a major contribution to its success in providing an excellent animal health and resource program at MIT. In addition, the laboratory has made significant contributions to other animal health and biomedical research programs in the Boston area and has added fundamental new knowledge to the field of laboratory animal medicine. The DCM Diagnostic and Investigative Laboratory, renamed to reflect our growing involvement in basic research, is now in its fourteenth year of NIH funding. On July 1, 1989, we submitted a five year \$2.37 million competitive renewal. Continuation of funding hopefully will ensue May 1, 1990. Our five year NIH postdoctoral training grant is now in its second year of funding. We currently have six postdoctoral fellows in our program. Four of our previous postdoctoral fellows have successfully passed their specialty boards; three in laboratory animal medicine and one in veterinary pathology.

DCM has recently been awarded two NIH grants totalling \$400,000 for equipment and minor renovation of our animal care facilities. These funds will help us maintain our facilities in accordance with NIH standards and USDA guidelines. Daily census of laboratory animals has increased approximately 25% during the last fiscal year. Of the average daily census, greater than 95% are rodents, the majority of which are mice. These numbers are reflective of the increasing use of transgenic mice for biomedical research. We are planning an expansion of transgenic facilities, including a transgenic surgery suite in E18 for FY 1990. Experiments conducted in 1980 indicated that, in principle, cloned genes derived from multiple origins could be incorporated into the genome of a mammalian embryo. Several laboratories subsequently proved experimentally that, after microinjection, the foreign DNA becomes integrated into cells from which the germ line is derived. Subsequent breeding could therefore establish pedigrees of animals carrying the new gene inserts. The term transgenic animal was applied. Two major contributions make transgenic technology a tremendously powerful tool in studying mammalian development and disease processes. First, foreign genes can be expressed in mice, and second, integration of new DNA can lead to insertional disruption and consequent inactivation of host genes. Transgenic mice at MIT are now being used to study immunology, oncology, genetic resistance to infectious diseases, and as models for gene therapy. It is extremely important, given the 'unique' feature of different transgenic strains, that the mice be maintained under strict barrier conditions. Limited access and health monitoring minimize the possibility of introduction of murine pathogens into the transgenic mouse colonies. Instituting these detailed and rigid protocols requires the combined resources of DCM's technical, veterinary and diagnostic support to ensure maintenance of transgenic mice under specified and constantly monitored parameters.

Staff and faculty at DCM have been busy conducting training seminars being provided by MIT per prescribed NIH policy for investigators, students and technicians involved in animal related research. DCM members are also involved as Principal Investigators or Co-Principal Investigators in 18 NIH, NCI or other federal or individual supported research activities. Extramural funding for FY 89 totalled 1.04 million and will increase to 1.27 million for FY 90. In addition, DCM has one pending grant submitted to NIH. In FY 1989, DCM staff and faculty have published one book, 15 papers, one chapter and 24 abstracts. In addition DCM staff and faculty have four chapters in press, 14 papers in press, 13 papers submitted for publication, and two in preparation.

We also sponsored our second summer short course entitled, "Infectious Diseases of Laboratory Animals: Recent Advances". We were gratified by the response with 45 attendees representing academia and industry from many parts of the United States. We intend to offer similar courses every two to three years.

James G. Fox

Energy Laboratory

The purpose of the Energy Laboratory is to conduct research that will result in better options for satisfying society's wants and needs for energy services. The Laboratory aims for that result by encouraging and assisting campus research on a broad range of energy issues, emphasizing multidisciplinary problems that involve people from most of MIT's academic departments. Current research activities address one or more of the following four broad questions: 1. How can fossil fuels, particularly low-quality fuels, be burned more efficiently, economically, and safely? (The word "safely" emphasizes environmental and health considerations.) 2. How can fossil, nuclear, and renewable energy resources be converted to more useful forms more efficiently, economically, and safely? 3. How can energy-intensive materials and methods be improved or replaced? 4. What are the interactions between energy, the economy, the regional and global environment, and society?

Professor Jefferson W. Tester was appointed Director of the Energy Laboratory in September 1988. Professor David C. White, the founding director of the Laboratory aided Professor Tester in managing the Laboratory during this year's transition.

The total volume of Energy Laboratory research during FY89 is estimated at \$8.7 million compared to \$10.2 million in FY88. The decline was largely anticipated since some programs ended and other principal investigators foresaw reduced funding from sponsors. Thus the Energy Laboratory program on the toxicology of inorganic combustion aerosols with Dr. Mary Amdur as principal investigator was transferred to New York University with Dr. Amdur's retirement from MIT and her appointment to the faculty there. Another program, "Electrical Injury," with Dr. Raphael Lee as principal investigator, was transferred to University of Chicago along with Dr. Lee who joined the medical school's faculty there. Another program, "The Performance Monitoring of Transformers," with Professor James Melcher as principal investigator, successfully completed the research phase and was transferred to industry for prototype development and commercialization. A small-scale effort supporting the commercialization phase continues to be funded under Professor Melcher's direction.

In March, the Center for Energy Policy Research conducted a two-day workshop on the MIT International Oil Markets Project. This workshop presented preliminary results from a study by Professor Morris Adelman of the history of international oil markets from 1969 through the present. Professor Adelman presented the main themes and results of his research with subsequent comments and discussion by panels of experts from industry, government, and academia.

In February, the Center for Energy Policy Research was rechartered as a joint center of the Energy Laboratory, the Department of Economics, and the Sloan School of Management. This organizational change formalizes the long-standing close relationship of the three groups.

Professor Jefferson Tester and David Wood are co-chairing a conference "Energy and the Environment in the 21st Century" to be held January 29-31, 1990. This conference, planned as an international activity, stresses the growing concern about the interdependency between energy and environmental systems. The program will address how technology and policy interact and affect environmental systems on a local and global scale. In May a conference co-chaired by Dr. Malcolm A. Weiss and Professor Thomas H. Lee and Professor Daniel Roos titled "Global Change: Processes and Prospects" was held at MIT. This conference discussed the current state of scientific knowledge on the emission and effects of greenhouse gases in the atmosphere.

A new program on the analysis of regional electricity alternatives in New England was initiated with Professor David C. White as principal investigator. Programs on health effects have increased with the addition of basic studies of mutagen formation during combustion of liquid hazardous wastes with Professor Adel F. Sarofim as principal investigator.

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Professor Kent Hansen is engaged in the creation of a major new international program aimed at enhancing the safe operation of existing nuclear power plants. The research focus will be on issues relating to the management of complex systems; the impact of public and/or corporate policies on relative safety; and the potential for new methods of sensing and diagnostics to assess plant status so as to avoid unexpected failures. The program is still under development; however, we have identified sponsors and gained commitments to participate from many elements of the international nuclear community.

Our sponsorship remains highly diversified with about half of fiscal 1989 funding coming from the private sector and about one quarter from the US Department of Energy; at one time DOE provided more than 60 percent of our support. Faculty and/or staff and/or students from 15 academic departments (plus 6 other MIT units) participated in Energy Laboratory projects during the year; no one department accounted for more than 25 percent of our volume. That diversity helps to maintain the multidisciplinary character of research we seek, and with faculty and student participation helps to integrate our activities into the teaching and research components of the Institute. The support of graduate education continues as a major role for the Laboratory, which supported 110 graduate research assistants for this fiscal year.

Specific research accomplishments during the year covered a large and diverse set of topics. Some of the topics of more general interest were summarized in our quarterly research bulletin, e-lab, under the following headings, grouped here in five categories:

Combustion and Fuels Research

- Removing Sulfur from Coal Gas at High Temperatures
- Coal Combustion: Predicting Ash Deposits Inside Utility Boilers
- Understanding Methane Reactions on Surfaces

Electric Power

- Electric Power Transformers: Monitoring Their Health
- Trade-off Analysis for Electric Power Planning in New England

Internal Combustion Engines

- Using Coal in Diesel Engines
- Understanding Knock in Engines

Energy Markets

- World Oil: Sufficient Resources, Unstable Market
- Effects of Energy Prices on Manufacturing Productivity

Other

- Ground-Level Ozone in Eastern North America: Its Formation and Transport
- Grinding: Predicting Fracture within Particle Beds

Information on all the projects active in the Laboratory during fiscal 1989 may be obtained from the report entitled Project Summaries, July 1, 1988 - June 30, 1989. The following paragraphs describe the major thrusts of the Energy Laboratory's principal research groups at the end of the year.

RESEARCH GROUPS

The Energy Engineering program focuses upon research in the engineering sciences needed to enhance energy use in technical industries. Active research areas include: thermal plasma materials processing, automated welding, engineering analysis and design methods, and fracture mechanics/fracture control. The research aim is to bridge the gap between the science base and existing industrial practice by providing methods, models, and data that will allow for the improvement of technical products and processes. (Professor David C. White, Program Director)

The Combustion Research Facilities program focuses on parallel modeling and experimental investigations with emphasis on the reduction of pollutant emission from fossil fuel combustion processes. A special feature of the experimental work is that fundamental flame data are obtained in a pilot flame combustion tunnel which simulates industrial plant combustion heat transfer conditions. Current research includes the reduction of the formation and emission of acid rain causing pollutants by combustion process modification, "real time" detection of trace concentrations of toxic compounds formed in toxic waste incineration, and the transformation and deposition of coal ash in pulverized coal fired boiler plant. Financial support comes from consortia of public utilities and chemical companies in the USA and Europe and from the US Department of Energy (DOE) and National Institute of Environmental Health Sciences (NIEHS). The research is carried out by faculty members and graduate students from the chemical, mechanical, and aeronautical departments and by Energy Laboratory research associates and technicians. (Professor János Beér, Scientific Director)

Research in the High-Temperature Reactions and Health Effects program determines the underlying chemical and physical processes responsible for desired and undesired emissions behavior in fuel combustion. A major collaborative effort among engineering, analytical chemistry, and toxicology examines the formation of mutagens from different fuels under different conditions of combustion, pyrolysis, and partial oxidation. Another activity, still in its formative stages, concentrates on unravelling the fundamentals of incineration of liquid and solid hazardous wastes. Efforts are also underway to develop a new cross disciplinary study of the generation, fate, and transport of indoor air pollutants from combustion and other sources. This endeavor will build on existing capabilities in engineering, analytical chemistry, and toxicology and involve new collaborations with the building technology program in the School of Architecture. (Professor John P. Longwell, Program Director; Dr. William A. Peters, Program Manager)

The Transportation Propulsion program conducts research, technology and policy studies relevant to internal combustion engines. Activities are based in the Sloan Automotive Laboratory and focus on engine performance, combustion and emissions, lubrication, as well as new propulsion system concepts for utilizing future fuel types, advanced materials, and engine electronic controls. (Professor John B. Heywood, Program Director; Dr. Victor W. Wong, Program Manager)

The Center for Energy Policy Research is organized to conduct policy research and to contribute to improved domestic and international energy policy-making through publications and conferences. Current research programs include: industry organization and regulation with emphasis on electric utilities; international energy markets, especially oil and natural gas markets; studies of energy demand, productivity, and economic growth; developing new methods of project and contract evaluation; and energy technology assessment. The Center's research programs are supported by corporations, governments, and non-corporate interest groups. These groups participate in conferences to discuss the Center's research and to work on topical energy policy issues. The work of the Center is done by faculty and students from several MIT departments, particularly the School of Management and the Department of Economics, and by professional staff members from the Energy Laboratory. (Mr. David O. Wood, Director)

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Research in the Environmental program seeks to identify and reduce the environmental impacts of energy-related facilities and involves a diverse range of research projects, including cooling systems for electric power plants, water management issues associated with coal development, controlling emissions of acid rain precursors, and assessing the impacts of acid rain and other local effects caused by atmospheric emissions. (Professor Adel Sarofim, Program Director; Dr. E. Eric Adams, Program Manager)

The Electric Utility Program serves to inform participating companies about ongoing MIT research activities, to identify and discuss utility needs and priorities, and to develop research projects responsive to those needs. The member organizations currently participating in the program include 17 utilities; 9 other organizations involved in supplying fuel, equipment, or services to the industry; and one government agency. (Dr. J. Derek Teare, Director)

The Nuclear program has the following broad objectives: 1) to provide direct technical contributions to nuclear plant reliability and safety; 2) to investigate possible improvements in nuclear plant design for more efficient utilization of nuclear fuel resources; and 3) to develop and communicate information to the public and nuclear power industry that will improve the efficient utilization of nuclear power. (Professor Neil E. Todreas, Program Director)

The Energy-Efficient Buildings and Systems program examines the behavior of existing buildings and components and seeks to develop new technologies with better energy efficiency. Current projects include indoor air quality models and measurements, new building envelope materials, replacement of ozone-depleting chlorofluorocarbons (CFC's) used in the manufacture of closed-cell foam insulation, and controls of building energy systems for improved efficiency. (Professor Leon R. Glicksman, Program Director)

The Mining and Excavation Research Institute is an industry-university consortium directed toward the development of advanced excavation technology for both mining and construction. The American Society of Mechanical Engineers provides a neutral umbrella for the cooperative efforts of about fifteen universities. In the energy area the program is directed toward advanced systems (remotely controlled and/or automated) for both coal and oil shale mining, and advanced concepts for hard rock drilling and for the construction and operation of underground nuclear waste repositories. (Professor Carl R. Peterson, Director)

PUBLICATIONS

During the past year, Energy Laboratory research resulted in 21 technical reports and working papers, and about 81 other publications (journal articles, workshop and conference presentations, etc.). Energy Laboratory Headquarters (E40-455, x3401) has available a complete list of reports, working papers, and other publications, as well as copies of Project Summaries and e-lab.

JEFFERSON W. TESTER and DAVID C. WHITE

Harvard-MIT Division of Health Sciences and Technology

INTRODUCTION

The Harvard-MIT Division of Health Sciences and Technology (HST Division) effectively links the educational resources of Harvard University and MIT in order to provide unusual educational and research opportunities to highly talented students desiring an education at the interface of technology and the medical sciences. The MD curriculum seeks to train physician/scientists. It provides a rigorous quantitative education in human biology, pathophysiology, and clinical medicine, and at the same time emphasizes the importance of independent research. The PhD Program in Medical Engineering/Medical Physics equips highly qualified engineers and physical scientists for independent research careers working on problems of significance to human health.

ADMINISTRATION

The Division continues to be administered by two co-directors working intimately with MIT Associate Provost Kenneth Smith and Harvard Medical School Dean for Academic Programs, James Adelstein. This administrative structure, although unorthodox in some respects, has continued to function smoothly and effectively. Faculty members from both Harvard and MIT work together to teach courses and to assume administrative burdens.

ACADEMIC PROGRAMS

Five new courses were developed by HST faculty and offered for the first time in Fiscal Year (FY) 89. HST 150 Principles of Pharmacology was offered in the Spring under the direction of Professor Richard Cohen. HST 180 Genetics and Molecular Medicine was offered in January under the direction of Drs. Richard Erbe, Nancy Hopkins, and David Houseman. (This course was offered jointly with the Department of Biology.) HST 220 Introduction to Patient Care and the Profession that Cares was offered in the Fall term by Professor Arnold Weinberg, Director of the MIT Health Services. HST 569 Photomedicine was offered in the Spring term and was directed by Professors Irene Kochevar, John Parrish, and Ernest Cravalho. This course represents a joint effort between MIT faculty and faculty at the Massachusetts General Hospital (MGH). Finally, HST 572 Emerging Medical Technologies was organized as a Spring course by Dr. James Weaver (MIT) and Ronald Newbower (MGH), and was open to the entire Harvard/MIT community.

A total of 205 graduate students were involved in HST degree programs during the past academic year. One hundred and fifty-five were MD candidates of whom 70 were simultaneously pursuing PhD degrees. There were 50 students involved in the doctoral program in Medical Engineering/Medical Physics.

Twenty-two HST students received the MD degree in June. Eight students received PhD degrees in Medical Engineering or Medical Physics.

The Admissions Committee has identified an outstanding class of approximately 38 new MD candidates for FY 91. In addition, 13 new MEMP students will join the Division, bringing the total enrollment to approximately 226.

We place considerable emphasis on research experience for students in the HST/MD Program. Indeed, the program is patterned closely after graduate education. We believe it is important for students preparing for careers as physician/scientists to engage in research under faculty supervision throughout their medical studies. The availability of funded Research Assistantships (RAs) makes this option feasible for many students, and also substantially reduces their debt load. The RA Program has been very popular with both students and faculty. During the Fall semester 45 HST/MD students were RAs, and during the Spring term 53 students participated in the program. Thirty-two percent of the students worked with MIT-based faculty and the remainder worked with HMS-based faculty in the teaching hospitals or at Harvard Medical School (HMS).

The HST FORUM, established as an annual event in 1987, celebrates the significance of student research activities in the Division. The scientific sessions of the 1988 HST FORUM were conducted in the auditorium of the Whitehead Institute and in the Whitaker College Building where approximately 40 presentations (10 platform talks and

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about 30 posters) were delivered. Students gained valuable experience in describing their research, and all participants profited by the diversity of disciplines which included Molecular Biology, Biomechanics, Chemical Engineering, Chemistry, Electrical Engineering, Genetics, Imaging, Mechanical Engineering, Physics, and Physiology. Following the scientific sessions, HST students met with a panel of physicians and scientists to discuss the topic of balancing career, family, and outside interests in a highly competitive environment. The FORUM ended with an evening dinner-dance which was well attended by both faculty and students.

The Master's degree in Health Sciences and Technology for HST/MD students, established last year by vote of both the MIT faculty and the Faculty Council at HMS, was formally instituted in September 1988. Henry Chueh (HST/MD 1989) was the first to obtain the MS in Health Sciences and Technology via MIT in June 1989. We expect more will follow in his path.

FACULTY AND STAFF

Dr. Irving M. London, Founding Director of HST, Grover Hermann Professor of Health Sciences and Technology, Professor of Biology at MIT, and Professor of Medicine at Harvard University, has reached Emeritus status. He will continue to teach in HST and to conduct his active research program in the synthesis of hemoglobin, the regulation of protein synthesis, and development of human gene therapy.

Dr. Glenn Rennels, MD, PhD, was appointed as the Cabot Assistant Professor of Artificial Intelligence in Medicine effective July 1, 1989. His appointment is joint between Electrical Engineering and Computer Science (primary) and HST (secondary). Dr. Rennels will also have responsibilities in the Department of Anesthesia at the MGH.

Lee Gehrke, Ph.D. was promoted from Assistant Professor to Associate Professor of Anatomy at both Harvard Medical School and in HST. Professor Gehrke was also named the 1989 recipient of the Irving M. London Teaching Award bestowed annually upon that faculty member who, through excellence and dedication to teaching in the Biomedical Sciences curriculum, best exemplifies the goals and philosophy of the Harvard-MIT Division of Health Sciences and Technology. Dr. Abul K. Abbas, Professor of Pathology at Harvard Medical School was the 1988 recipient of the London Teaching Award.

Dr. Federico Welsch, Executive Officer to the HST Committee on Research Development, left to assume the post of Associate Director of the National Cancer Institute for International Affairs. His presence among us will be missed.

RICHARD J. KITZ
ROGER G. MARK

Mining and Mineral Resources Research Institute

The Mining and Mineral Resources Research Institute (MMRRI) of MIT is a focal point for mineral related activities at MIT. It is affiliated with the Mineral Resources Program of the Bureau of Mines from which it receives some financial support. It also continues to participate in the Program on Respirable Dusts and the Generic Mineral Technology Center for Pyrometallurgy of the Bureau of Mines. A new program of research on innovative smelting methods for the production of steel is now being funded as part of the "Steel Initiative", a program jointly supported by the American Iron and Steel Institute and the United States Department of Energy. Personnel from the MMRRI are being supported by the Strategic Materials Office of the Defense Logistics Agency to provide technical leadership for a new program on plasma smelting of ferrochromium. A 1.5 megawatt plasma smelting furnace is being installed in the Charleston, SC, plant of the Macalloy Corporation, and a test program for use of state-of-the-art smelting methods is being developed for smelting ores available to the domestic ferroalloys industry. The broad goal of the program is to enhance the technological base of that part of American industry. Other participants in the program are the Macalloy Corporation, the South Carolina Research Authority, and Clemson University.

Funds available in the Allotment Grant for the MMRRI have been utilized to support the work of two undergraduates in the REMERGENCE Laboratory, and a total of five graduate students in the Departments of Civil, Mechanical, and Materials Science and Engineering Departments. In addition, limited funds have been utilized for purchasing capital equipment for mineral related activities in these Departments.

JOHN F. ELLIOTT

Northeast Radio Observatory Corporation/Haystack Observatory

The Haystack Observatory is a research center engaged in radio astronomy, geodesy, atmospheric science, and radar applications. Parts of its programs are conducted under the auspices of the Northeast Radio Observatory Corporation (NEROC), a consortium of thirteen educational and research institutions* in the northeast. The Observatory receives financial support from the National Science Foundation (NSF), the National Aeronautical and Space Administration (NASA), the Department of the Air Force through MIT Lincoln Laboratory, as well as from other federal agencies and national programs.

The Observatory instrumentation at Haystack consists of a 37m diameter paraboloidal antenna enclosed in a radome that is used for radio astronomical observations at wavelengths from 6 mm to 18 cm. Observatory instrumentation also includes the 18m radio telescope at Westford operating at wavelengths of 3.5 and 13 cm for geodetic Very Long Baseline Interferometry (VLBI) observations, two powerful processors that correlate the VLBI data obtained globally, and two large radar antennas (46m and 67m) that are used in ionospheric and atmospheric studies. During the past year, about 300 researchers from US and foreign institutions used the Observatory instrumentation, including a large number of graduate and undergraduate students as part of their educational programs. In addition, the Observatory is participating in the NSF Research Experiences for Undergraduates program, allowing students from MIT and other area universities to learn about and contribute to our research programs during the summer months. An effort has also been initiated to allow Haystack researchers to contribute to science and mathematics education in the local area schools.

During the past year, the major achievement of the Observatory was the completion of the upgrade of the 37m radio telescope, resulting in the doubling of its aperture efficiency at a frequency of 43 GHz. A program to continue this upgrade with the goal of developing an observing capability at 115 GHz by 1991 has been approved, and this will allow Haystack to observe interstellar molecular lines at higher sensitivity and angular resolution than presently achievable in the U. S..

The current 43 GHz efficiency of 17 percent near 40 degree elevation angle corresponds to an rms surface tolerance of 0.48 millimeters. The surface was aligned for a zero temperature offset between the surface panels and more massive splice plate, removing the requirement that the active thermal control system maintain a colder splice plate. Much of the work in the 43 GHz alignment program was oriented towards increasing our knowledge of the antenna structure and its response to gravitational and thermal effects. This was done in preparation for the major upgrade program for operation at 115 GHz where active compensation for gravity and thermal effects will be required. During 1988, we have developed many of the tools and techniques necessary for this next project. These include an operational procedure for making holographic surface maps, special tools for accurate surface alignment, and the generation of an improved antenna model by our mechanical consultants, Simpson, Gumpertz and Heger, Inc. of Arlington, MA. We have also made operational improvements to the telescope, such as the use of subreflector tilt to compensate for feed offset, and the replacement of the 1000 channel spectrometer's DEC PDP-11 control computer with a modern LSI-11, which now also provides two separate signal-channels for spectral line astronomy.

*Boston University, Brandeis University, Brown University, Dartmouth College, Harvard University, Harvard-Smithsonian Center for Astrophysics, MIT, Polytechnic Institute of New York, State University of New York at Stony Brook, Tufts University, University of Massachusetts, University of New Hampshire, and Yale University.

In the past year the low noise 36–49 GHz (0.7 cm wavelength) maser amplifier receiver has continued to be used very effectively. A study of the galactic center source SgrA using a methanol transition at 36.2 GHz has substantiated the suggestion that two molecular clouds are fueling the galactic center source. Maser emission indicated by narrow, intense features is observed at the shocked interface of these clouds with SgrA and a supernova remnant. Further methanol maser emission at 37.7 GHz in addition to the lines presently detected at 38.3 and 38.45 GHz has been observed in NGC6334F and W3OH which are two regions of active star formation also containing ionized hydrogen gas. Haystack possesses a unique measurement sensitivity in this frequency band amongst U. S. radio observatories.

Highlights of single antenna astronomy research in the past year in the 20–25 GHz band (1.3 cm) included the observation of an almost periodic occurrence of flares in the 470 km s^{-1} feature in the water vapor spectrum of the nuclear maser source in the galaxy NGC4258. The highly luminous ($500 L_{\odot}$) extragalactic maser source in the galaxy NGC3079 continues to be very stable. This characteristic is highly unusual for all known maser sources. In addition, dark clouds (regions of high extinction) and high velocity mass outflow sources in our galaxy were studied using the inversion transitions of the ammonia molecule, and allowed molecular cloud parameters such as temperature and density to be obtained.

As part of its Very Long Baseline Interferometry (VLBI) program, Haystack operates the Mark III and IIIA correlators side-by-side, employing seven playback drives split simultaneously between the two independent processors. Correlator throughput is consequently up by 40%. Computing resources within the VLBI group have also been augmented with the addition of Sun workstations for post-processing and analysis.

Research highlights during the past year include first fringes from the Very Long Baseline Array (VLBA) antennas, using the acquisition system designed and constructed by Haystack. The Pietown VLBA site was operated as part of several U. S. VLBI Consortium Network observations, and the data were correlated at Haystack. Phase-referenced VLBI, organized through the current VLBI Network, has shown that the active radio component in the Algol star system is indeed the close binary and not nearby Am stars. Similar high accuracy VLBI positions for the RS CVn binaries UX Ari, HR5110, and σ CrB have yielded VLBI proper motion measurements. The accuracy of better than 1 milliarcsecond/year was obtained with a span of only 2–3 years, while 50 years or more of ground-based optical data are required to approach such accuracy. Early main-sequence stars have been detected in weak, continuum emission. Radiospheres of a few stellar diameters were found to surround three magnetic B-stars, including the young star S1 which appears to have just evolved onto the main sequence. Quiescent emission at 8.4 GHz has been detected from 3 red dwarf (dMe) flare stars in the solar neighborhood. No star exceeded 5 mJy during the observations, but antennas of the Deep Space Network, the VLA, and wideband Mark III recording allowed YZ CMi, Wolf 630AB, and EV Lac to be measured with VLBI. Emission mechanisms can now be tested, but a long-term goal will be planetary and brown dwarf searches via milliarcsecond VLBI astrometry. Mark III sensitivity has also permitted observations of 5 double hotspots in extragalactic radio sources. The compact hotspots are sites of particle re-acceleration far from the central energy source, and offer an unusual opportunity to study the interaction between relativistic particles and the intergalactic medium at high redshifts.

The accurate geodetic measurements made using VLBI under the NASA Crustal Dynamics Project continue to provide surprising results. The southern coast of Alaska at Cape Yakataga, which last year was reported to show smooth compression over the 1984–1987 period, appears to have lurched to the west by as much as 8 cm in the interval 1987–1988. During this time there were two large earthquakes off the coast which geophysicists speculate may have resulted in the observed offset. The measurements planned for summer 1989 should clarify this crustal movement. While these observations are continued as part of the operational program, a series of experiments intended to improve the accuracy of the VLBI technique for geodesy has achieved a repeatability of 1 part per billion in the length of the baseline from Massachusetts to California for 17 observations in 1987 and 1988.

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Haystack has continued to contribute to the development of the nation's Very Long Baseline Array (VLBA), which consists of a 10-element array of 25-meter telescopes covering the continental USA, Hawaii and St. Croix. Haystack is responsible for the development of the data acquisition systems of the VLBA; this includes design and construction of a prototype of the digitization and high-density recording sub-systems. The VLBA recorder and digitization electronics built at Haystack have now been successfully used at the first VLBA telescope in Pie Town, New Mexico. As noted above, first fringes between Pie Town and the VLA site were obtained during the past year using the Mark IIIA processor at Haystack; the Haystack processor will continue to support the VLBA as more antennas come on line and until the VLBA processor is complete. Additional recorders for the other VLBA sites and VLBA processor are now being built at Haystack. Haystack has transferred the digitization electronics design to NRAO and additional data acquisition electronics for the VLBA are being built at NRAO. Haystack is also in the process of transferring the recorder technology to industry. The recorder head-stack will be available from Honeywell, and complete VLBA recorders can be obtained from several U. S. companies. Haystack is planning to continue recorder development to provide higher data rates for future enhancements of the sensitivity of the VLBA and other VLBI networks. The VLBA, which is under the direction of the National Radio Astronomy Observatory, and funded by the NSF, will provide VLBI scientists, including those at the Haystack Observatory, with a powerful high resolution astronomical instrument.

The Observatory's Atmospheric Sciences program uses the Millstone Hill UHF radar together with on-site optical and related ground-based remote sensing instrumentation to investigate upper atmospheric and ionospheric energy sources, and to study the global coupling mechanisms as a part of the NSF-sponsored CEDAR program (Coupling, Energetics, and Dynamics of Atmospheric Regions). Enhanced radar data acquisition techniques developed as a part of this program were used for studies of the thermal structure and circulation in the lower thermosphere between 100 and 150 km altitude, and the coupling between the thermosphere and the exosphere. During the past year, the effects of the increasing solar activity cycle were monitored and magnetic storm effects were emphasized in the observational program. Intense heavy ion outflow from the topside F-region of the ionosphere has been identified at mid-latitudes during magnetic storms, and was found to provide a significant source of oxygen ions in the high-altitude magnetosphere. The absolute intensity of plasma waves and the effects of wave-wave coupling in the auroral E-region have been determined in high time and spatial resolution studies of coherent radar backscatter. Finally, a complete structural analysis of the 46m Millstone steerable antenna was completed and a program to strengthen and better maintain this instrument was begun.

JOSEPH E. SALAH

Nuclear Reactor Laboratory

During the past year the Nuclear Reactor Laboratory (NRL) continued and strengthened its joint interdisciplinary activities with both MIT and non-MIT collaborators: 10 MIT academic departments and interdepartmental laboratories, and 40 other universities, schools, and nonprofit research institutions, such as teaching hospitals. These joint research or teaching and training activities cover a wide spectrum in the life and physical sciences and in engineering, including development of a brain cancer therapy, nuclear engineering, computer control of reactors, training in reactor operations, and radiochemistry and trace analysis applied to the health effects of energy use, nutrition, earth and planetary sciences, archeology, and nuclear medicine.

Especially noteworthy developments were the design, fabrication, and initial operation of the pressurized water in-pile loop studies aimed at radiation dose and corrosion reduction in light water power reactors, and the continued program in joint research with Tufts-New England Medical Center on the treatment of brain cancer utilizing the boron neutron capture method.

A new major project on irradiation-assisted stress corrosion cracking was initiated with support from a Japanese company. The in-pile dose and corrosion studies have evoked increased interest and have provided opportunities for major continuing research efforts. Our research in computer control of reactor power has continued to lead all other similar efforts in the USA.

NEUTRON BEAM TUBE RESEARCH

One of the MIT Research Reactor (MITR) beam tubes is now being utilized for prompt gamma activation analysis. The initial need is for rapid analysis of B-10 in blood and tissue. This is related to our brain cancer project. There are many additional uses for the prompt gamma facility, which we expect to use for elemental analysis on elements difficult to detect by delayed emission gamma activation analysis.

RADIOCHEMISTRY AND TRACE ANALYSIS

Professor Frederick A. Frey, Department of Earth, Atmospheric, and Planetary Sciences, and research colleagues utilize the MITR for trace element analyses of geologic materials by neutron activation analysis (NAA). The activation analysis laboratory dedicated to geochemical studies is supervised by Professor Frey and Dr. Pillalamarri Ila and utilized by approximately five MIT graduate students, plus several visiting scientists from foreign countries and other US universities. Analyses of lavas from recently active volcanoes are emphasized with the objectives of identifying the mineralogy and composition of their source and the ascent paths of lava in the volcanic systems. A new project begun this year is the study of a 5000 km long chain of extinct volcanoes which form a north-south trend in the eastern Indian Ocean. These volcanoes reflect the separation and northward movement of India from Australia-Antarctica. Samples were obtained from these now submerged volcanoes by the Ocean Drilling Program.

During 1987-88 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) has been continued by Dr. Ilhan Olmez. 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 Woods Hole, the University of Washington, the State University of New York at Buffalo, and Fairfield University. Commercial organizations that utilized the NAA expertise of NRL during the past year were GTE, Waltham and Danvers, Massachusetts; Northeast Utilities, Hartford, Connecticut; Spire Corp., Massachusetts; and Pennsylvania Power and Light Co., Pennsylvania.

Within MIT, research support has been provided to several departments. Dr. Olmez has worked with Professor Adel F. Sarofim (Chemical Engineering), using multi-element NAA, to characterize the products of combustion with the ultimate goal of reducing environmental releases. Impurities in different materials were identified for

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Professor Otto K. Harling (NRL) and Professor Michael J. Driscoll (Nuclear Engineering) for their in-pile coolant loop project. Barium and titanium ratios were determined in Ba, PbTiO₃ for Dr. W. E. Rhine and Quinio Saegusa (Ceramic Processing Research Laboratory), and attempts have been made to determine impurities in pure indium for Professor A. F. Witt (Materials Science).

Dr. Olmez has been actively engaged in a number of environmental research projects. Financial support has been obtained from the Pennsylvania Power and Light Company and Northeast Utilities in Connecticut to study groundwater contamination at the Montour Steam Electric Station and the West Springfield Power Plant; and from different utility companies, through the MIT Electric Utility Program, to examine inhalable atmospheric particles in the Boston area.

A number of other research applications of NAA are summarized in a subsequent section, Reactor Irradiations and Services for Research Groups outside MIT.

NUCLEAR MEDICINE

Neutron capture therapy for cancers is, in principle, a uniquely attractive method of using radiation to destroy tumor cells without significant damage to healthy cells. Boron neutron capture therapy (BNCT) research and testing has a long history at the MITR, going back to the middle 1950s. Currently interest in this technique has greatly increased due to the apparent successes of Dr. Hiroshi Hatanaka of Japan, who has now used this therapy on approximately 100 people. Dr. Hatanaka became acquainted with BNCT when he worked at MITR during the early trials. At the present time Professor Otto K. Harling has arranged a collaboration with several senior staff from the Tufts–New England Medical Center. Funding for a three-year project has been received from the United States Department of Energy (DOE). The \$1.2M grant will be enhanced by the support provided through MIT and the Tufts–New England Medical Center. This project completed its second year with good progress on all tasks. As part of this year's efforts, MIT arranged and hosted an international workshop on epithermal beam development for neutron capture therapy.

The MIT Reactor also supports nuclear medicine programs conducted by several hospital and radiopharmaceutical groups outside MIT. A summary of these activities is provided in a following section.

RADIATION HEALTH PHYSICS

The NRL supports a new subdiscipline in the Nuclear Engineering Department (NED), Radiation Health Physics, by providing relevant research opportunities and a specially designed laboratory/demonstration course. This course, 22.09-22.59 Principles of Nuclear Radiation Measurement and Protection, has been reorganized so that it is appropriate for all students in NED. This restructuring has also permitted reduction of NED courses by one course. The Radiation Health Physics program is under the direction of Professor Harling and Francis X. Masse, MIT Radiation Protection Officer. The program is designed to produce graduates who are well educated in nuclear engineering fundamentals as well as in the basics of radiation measurement, management, and protection. Basing this activity at the NRL is particularly appropriate since the MITR provides excellent opportunities to learn many aspects of this subfield in a realistic environment. Support for graduate students has been obtained from the Institute of Nuclear Power Operations and from several nuclear utilities.

COMPUTER CONTROL OF REACTORS

Dr. John A. Bernard of the NRL and Professor David D. Lanning, Nuclear Engineering Department, continued studies on the closed-loop, digital control of nuclear reactors during both steady-state and transient operation. Assistance was received from Professors Allan F. Henry and John E. Meyer (NED) and from Dr. Takashi Washio, a visiting engineer from Tohoku University in Japan. A general set of control principles, based on reactivity constraints and intended for nonlinear conditions, has been deduced and experimentally demonstrated on the MIT Reactor. This approach is unique in that it is based on the general equations of reactor dynamics rather than on measurements of specific response characteristics. This work is currently supported by the United States Department of Energy, by the Sandia National Laboratories (SNL), and by the Oak Ridge National Laboratory.

It has resulted in 17 publications during the past year. In addition, a major report summarizing both the theoretical and experimental work performed in this area from 1986 to 1988 has been issued. This report complements an earlier one that covered the years 1983-1986. The 'reactivity constraint approach' has been licensed by the United States Nuclear Regulatory Commission (NRC) for general use on the 5 MW MIT Research Reactor. Closed-loop control experiments can be performed without a priori restrictions on the associated reactivity. The significance of this license approval is that 1) no other research reactor in the United States has such a broad approval for closed-loop control and 2) a precedent has been established for our approach regarding such control. This gives the reactivity constraint concept an enormous lead over competing ideas in the United States. Complementing the reactivity constraint approach has been the development of the MIT-SNL Period-Generated Minimum Time Laws, which are closed-form expressions for the time-optimal control of power in reactors subject to restrictions on the minimum allowed period. These permit reactor power to be changed by many orders of magnitude both in a few seconds and without overshoot. These laws are unique in that they are time-optimal and yet both operate in real time and incorporate feedback. A major accomplishment of the project during the past year was the extension of the MIT-SNL laws to the performance of automated reactor startups. Research in progress includes: 1) the development of methodologies for the control of core average temperature, 2) estimation of the degree of subcriticality of a nuclear reactor, 3) the extension of the non-linear closed-loop control techniques to the operation of large reactors that are characterized by spatial dynamics, 4) causal analysis, and 5) continued work on control laws for the rapid maneuvering of a reactor's neutronic power. Two B.S., four M.S., and three Ph.D. degrees were granted during the past year for research performed on this project. There are currently three M.S., one N.E., and three Ph.D. theses in progress on topics related to this research. Demonstrations of the technology are available by appointment. In a related development, Dr. Bernard and Dr. Washio published a book entitled Applications of Expert Systems within the Nuclear Industry. Also, Dr. Bernard was the recipient of the American Nuclear Society's 1989 Young Member Engineering Achievement award.

DOSE REDUCTION IN NUCLEAR POWER REACTORS

A major interdisciplinary and interdepartmental research program designed to develop radiation dose reduction technology for the nuclear power industry is in progress. It is supported by the Empire State Electric Energy Research Corporation (ESEERCO) and the Electric Power Research Institute (EPRI). Funding at the level of \$2.5 million for four years is available to support the project. Radiation fields in the primary coolant system of today's light water reactors are undesirable from a health viewpoint and have a significant negative impact on plant capacity factors by impeding maintenance tasks. The principal goal of the project is to reduce the radiation fields to which workers are exposed. Studies of how these fields are built up and methods for minimizing them will be conducted with the aid of small-scale coolant circulation loops installed in the core of the MIT Reactor, designed to simulate (in separate loops) conditions that exist both in pressurized-water reactors and in boiling-water reactors. The formation, transport, and deposition of corrosion products in the coolant is being characterized, and tests are under way to obtain information about optimized water chemistry, surface treatments, and other parameters. Principal investigators are Professor Otto K. Harling (NRL) and Professor Michael J. Driscoll (NED). Others already participating are Dr. Gordon Kohse and Dr. Ilhan Olmez, of NRL; members of the MIT Reactor staff; Professors Ronald G. Ballinger and David D. Lanning of NED; Dr. William Lindsay, an expert consultant in the field of reactor coolant corrosion studies; and a growing number of MIT students from the Nuclear Engineering Department. Four utilities – Public Service Electric & Gas, Duke Power, Northeast Utilities, and Boston Edison Co. – have provided additional financial support. These projects utilize the MIT Reactor directly and provide much needed support for experimental research in nuclear engineering. It is expected that two to four graduate students will continue to be involved in this project.

Further support for future research in these areas is likely and negotiations for ongoing research and testing are in progress.

IRRADIATION-ASSISTED STRESS CORROSION CRACKING

A new project based on the technology in our loop project started in September of 1988 with support from the Electric Power Research Institute and the Tokyo Electric Power Company. This four-year project is supported at the \$500,000/year level and will address some of the issues associated with irradiation-assisted stress corrosion

cracking (IASCC). Extended reactor usage and lifetime prolongations have raised the issue of IASCC in light water power reactors (LWRs) to a high priority. The expertise which we already have in in-pile testing under LWR conditions and our experience in stress corrosion cracking (Professor Ronald G. Ballinger) and nuclear materials testing (Professor Otto K. Harling) were combined to develop a successful proposal for this long-range intellectually stimulating project.

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 and in other area hospitals for cancer therapy; 2) research activities by Professor Webster S.S. Jee's group at the University of Utah Radiobiology Laboratory using animal models; 3) production of Pt-197 and Os-193 Mössbauer sources for the Chemistry Department at Northeastern University to study the chemistry and structure of gold compounds, particularly those exhibiting anti-arthritis and anti-tumor activity; 4) production of Dy-165 for Dr. Clement B. Sledge of Brigham and Women's Hospital for research studies in the treatment of arthritis, and for Cadema Medical Products, Inc., Middletown, New York, for development of the commercial Dy-165 radiopharmaceutical; 5) use of the reactor by Cadema Medical Products, Inc., to produce holmium-166 for a feasibility study since this nuclide appears to possess superior properties for radiation synovectomy of rheumatoid arthritis; 6) assistance to Cadema Medical Products, Inc., in preclinical trials of radiation synovectomy with both Dy-165 and Ho-166 (Cadema has recently terminated their nuclear medicine program); 7) 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 8) investigations by McDonald Wrenn of the University of Utah using track etching techniques to determine the lower detection limit of uranium in water.

In a number of other areas, also, reactor irradiations and services were performed for research groups outside MIT. Some of these represent new activities, while a number are continuations of previous research: 1) samples of aluminum oxide were irradiated for Dr. Forrest C. Burns at the US Army Materials Technology Laboratory, Watertown, Massachusetts, to determine their elemental content by neutron activation analysis; 2) Dr. James Anderson of the Aircraft Instruments Department of General Electric continued studies of fast neutron damage to liquid crystal displays, 3) personnel from the MIT Radiation Protection Office in collaboration with the Yankee Atomic Electric Co. irradiated microspheres of Co-59 for use in dose deposition studies; and 4) Dr. William Brown of the Lincoln Laboratory used the fast spectrum irradiation facility to perform electronic hardness tests on different types of "Field Effects Transistors." Additional NAA services, including many for research groups outside MIT, are reported above in the section, 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 341 students and 119 faculty and staff from 38 other educational institutions benefited from visits to and use of the MITR during the past year. Popularity of the sharing program continues to grow.

Research utilization of the MITR by other institutions under the Reactor Sharing Program during the past year has included: 1) use by Professors J. Christopher Hepburn and Rudolph Hon of Boston College to activate geological specimens and standards for the NAA of rare earth and other trace elements in studies of the geological development of the northeastern US; 2) use as a neutron source for calibration of a new high pressure ion chamber design for Harvard University Medical School and the University of Leeds, England; 3) analysis of sediments by neutron activation for Woods Hole Oceanographic Institute; 4) analysis of rock specimens by neutron activation for Boston College; 5) neutron activation analyses for the State University of New York, Buffalo; 6) neutron activation analyses for the University of Washington; 7) irradiation and analysis of ancient ice samples from the South Pole by NAA for Dr. Edward Fireman, Harvard-Smithsonian Astrophysical Observatory, in preliminary studies to learn whether or not we can determine natural or anthropogenic contamination of ice at those very low concentrations; 8) gamma irradiation of plant seeds for several area high school students participating in science fair projects; 9) study of the daily intake of metals by Mariana Island natives, who suffer from a fatal

neurodegenerative disease that offsets collagen synthesis and maturation, in collaboration with Dr. D. B. Hanson, Forsyth Dental Center, Bioengineering Department; 10) ongoing research to identify elements other than lead for motor vehicle emissions in collaboration with Professor G. E. Gordon, University of Maryland; 11) analyses performed for Professor T. Spengler, Harvard School of Public Health, to determine sources of indoor air pollution; and 12) determination of alpha activities from polonium-210 decay for the purpose of comparing the radioactivity content of marijuana and tobacco for the University of Massachusetts, Worcester.

For education of the general public and students at all levels in local and other New England schools, the reactor staff provides lectures and tours periodically throughout the year. Several local universities incorporated reactor visits and experiments into their regular course curricula, as follows: 1) Northeastern University, Mechanical Engineering Department, Nuclear Engineering I, Course NE 2541, 17 students, 15 visits; 2) Northeastern University, Physics Department, Course PHY 1555, 5 students, 2 visits; and 3) the University of Massachusetts, Harbor Campus, Department of Physics, Physics 603, 29 students, 6 visits.

An educational program to familiarize high school science teachers with the scientific, engineering, and medical uses of nuclear research reactors and to involve the teachers in typical applications and experiments, with a special lecture and demonstration by the MIT Radiation Protection Office, is also funded by the USDOE Reactor Sharing Program. Two seminars were held for teachers (one four-hour day each) with positive response from 41 attendees.

MIT RESEARCH REACTOR

The MIT Reactor completed its 30th year of operation, its 14th since the 1974-75 shutdown for upgrading and overhaul. During the past year the reactor operated on a Tuesday through Friday schedule with Mondays used to prepare for the installation of 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 55 hours per week with 44 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 242,730 megawatt-hours at June 30, 1989. The MITR-I generated 250,445 MWH in the sixteen years from 1958 to 1974.

To summarize briefly the reactor utilization described in more detail above, it was well utilized during the year, although still more experiments and irradiations can be accommodated due to the number and versatility of its many facilities. The reactor, as an integrated whole, continues to be used in a series of experiments designed to demonstrate the feasibility and advantages of reactor control by digital computer. A pressurized loop for a major new interdepartmental project on dose reduction for power reactors is installed in the reactor. The production of dysprosium-165 was increased for distribution to New York as well as to Boston for arthritic knee therapy. A new major project on irradiation-assisted stress corrosion cracking was initiated with US and Japanese support. The number of specimen irradiations was 1226. Theses and publications on research supported by the reactor are running at about 20 and 60 per year, respectively. A total of 1242 people toured the MIT Research Reactor during 1988.

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 part way through the production of another batch of fuel for the MITR-II.

During the past year, in connection with the generic question of such support for university reactors, the National Academy of Sciences-National Research Council (NAS-NRC) has completed a study to assess the value and costs of university research reactors and whether the Federal government provides adequate financial assistance for their operation and the research programs that they support. Federal funding falls far short of the assistance provided by the Department of Energy and the National Science Foundation to a number of US universities for operation and utilization of particle accelerators; it is also much less than several European governments provide for support of their university class research reactors. In connection with this study Professor Otto K. Harling of the NRL assisted NAS-NRC to accumulate detailed information regarding research reactor accomplishments. A report favorable to the needs of university research reactors has been completed and issued by the NAS-NRC

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committee. MIT is leading the effort for the entire university research reactor community to obtain rational funding levels for these facilities from federal sources. In spite of budget constraints, progress has been made in Congress to develop this new support base and a bill favorable to university reactors has passed the US House of Representatives and is now being considered by the US Senate.

OTTO K. HARLING

Operations Research Center

The Operations Research Center (ORC), established in 1953 as an interdepartmental graduate degree program, completed its 36th year of continuous operations in 1988-89. The year was marked, on the one hand, by the continued success of the Center's educational programs coupled with a significant increase in its research activities and, on the other, by intensive planning for future development.

Highlights of the year included: extensive discussions involving approximately 35 faculty and staff from throughout the Institute concerning the establishment of a Decision Sciences Center at MIT; graduation of one of the largest master's degree classes in the history of the ORC and admission of one of the largest and most outstanding incoming classes for September 1989; a wide variety of methodological and applied research projects; continuing emphasis on increasing the external visibility of the ORC; and a number of individual distinctions for our students and affiliated faculty and staff. This report provides some details on these 1988-89 activities and reviews briefly the ORC and its educational and research programs.

FACULTY AND STUDENTS

Three new faculty and senior research staff became affiliated with the ORC this year, bringing the total number to 34. Faculty are drawn from the School of Management and the Departments of Electrical Engineering and Computer Science, Civil Engineering, Mathematics, Aeronautics and Astronautics, Ocean Engineering, Mechanical Engineering, Urban Studies and Planning, and Nuclear Engineering. Thomas L. Magnanti, George Eastman Professor of Management Science, and Amedeo R. Odoni, Professor of Aeronautics and Astronautics and of Civil Engineering, continued as the Center's Codirectors, and Marcia V. Chapman served as the Assistant Director.

The Operations Research Center offers two interdepartmental graduate degree programs, one leading to a PhD degree in Operations Research and the second leading to a master's degree. During 1988-89, these programs enrolled 51 students--32 PhD candidates and 19 SM candidates. It conferred 16 master's degrees, the highest number ever for the ORC, and one PhD in operations research. Several other PhD theses were in the final stages of completion in the summer of 1989, and three more PhD degrees will be awarded by September 1989.

For the Fall Term of 1989-90, the ORC expects an incoming class of 18 students - the largest incoming group in its history. Eight of these new students are foreign (from eight different countries) and seven are women. They were carefully selected from one of the most outstanding pools of applicants in memory. (As an example, 29 of this year's applicants had a 790 or 800 score (out of a maximum of 800) in the quantitative portion of the Graduate Record Examination.)

ACADEMIC PROGRAMS

The ORC's academic programs, well-known for their quality, continued in much the same manner as in previous years. In accordance with the recommendations of the 1986 report of the Committee to Review Operations Research at MIT, the Center instituted a writing requirement with the incoming class in Fall 1988, as well as a computer literacy requirement.

This year the School of Engineering introduced two new schoolwide electives in the undergraduate curriculum covering operations research topics: Probabilistic Models in Engineering and Engineering Systems Optimization. Two other electives in the areas of decision analysis and data communications may be added in the future.

The ORC expanded its computer resources in early 1989 with three AT&T 6386s, three AT&T 6312s and three AT&T 477 color printers. This equipment nicely complements our existing Macintosh and VaxStation network and IBM PCs to provide a versatile facility for both word processing and computational needs.

RESEARCH ACTIVITIES

During 1988-89, the volume of research conducted directly through the ORC grew significantly. This work, nonetheless, represents but a small fraction of OR-related research carried out throughout the Institute by ORC affiliated faculty and staff. Research activities spanned a wide spectrum of methodological topics and

applications and ranged from small, unsponsored projects involving a single faculty supervising a student's thesis to much larger, sponsored programs involving several faculty/staff and students.

Examples of primarily methodological research topics include work on: mathematical programming and combinatorial optimization, including modeling languages for integer programming, projective transformation methods for linear programming, polytopes, and cluster analysis; parallel and distributed computation and algorithms; network optimization and network design with an emphasis on the development of extremely efficient algorithms for solving classical problems; probabilistic combinatorial optimization problems - a new class of very interesting probabilistic variations of standard combinatorial optimization problems; facility location in both deterministic and stochastic settings; queueing theory under both static and dynamic conditions; quantifying the equitability of queueing systems; analysis of queueing networks; stochastic processes; classical and Bayesian statistics; and decision analysis and statistical decision theory.

ORC faculty are also currently investigating several major areas of application including: flexible manufacturing systems; financial services; marketing; transportation systems; air traffic control; public services, such as urban emergency systems; criminal justice; safety and risk analysis in air transportation, communication systems, nuclear engineering and epidemiology; and industrial production and transportation logistics.

Several organizations sponsored research projects at the ORC during 1988-89, for example: the National Science Foundation (several projects); the C.S. Draper Laboratory (several projects and Draper Fellowships); MIT's Lincoln Laboratories; the National Institute of Justice, the Department of Transportation; the Office of Naval Research, the Air Force Office of Scientific Research; AT&T; IBM; and the Human Services Research Institute.

OUTREACH PROGRAMS

The ORC and its faculty and staff, in their effort to serve the professional community at large, regularly undertake a number of outreach activities.

For instance, the ORC offers professional courses during the Summer Session. It offered two such programs, "Decision Analysis: Basic Concepts and Applications" and "Decision Analysis with Multiple Objectives: Concepts and Applications," during the summer of 1988.

The ORC has also initiated an "OR Clinics" program under which the Center arranges half-day workshops focused on a particular problem presented by representatives of a company. Four such clinics took place this year, two for the Campbell Soup Company and one each for the Dow Chemical Company and for United Parcel Service. We are pleased that this program provides a useful service to our colleagues in industry and at the same time gives participating faculty and graduate students added insights into problems currently faced by major companies.

In the same general view ORC faculty, in cooperation with the Center for Transportation Studies, presented in June 1989 a one-and-a-half day symposium on "Managing Transportation Systems in the Face of Uncertainty." Seven ORC faculty and alumni gave presentations on topics that reflect the cutting edge of current research on applications of stochastic processes. Twenty-four 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 Peter Hammer, from RUTCOR, Rutgers University; Jan Karel Lenstra, from Erasmus University, Rotterdam and CWI, Amsterdam; Carl Harris, from the Department of Operations Research, George Mason University; Louis Riccio, from the Department of Transportation, New York City; and Donald Gross, from the Division of Electrical, Communications, and Systems Engineering, National Science Foundation. The Operations Research Center also cosponsored a special lecture series for Distinguished Women in Operations Research and Engineering. This series was funded by the National Science Foundation and cosponsored by the Center for Transportation Studies at MIT. The speakers were Margaret Wright, AT&T Bell Laboratory; Judith S. Liebman, Vice Chancellor for Research and Dean of the Graduate College, University of Illinois at Urbana-Champaign; Marguerite Frank, Mathematics Department, Stanford University and Department of Decision Sciences, Rider College; Karla Hoffman, Department of Operations Research and Applied Statistics, George Mason University, and Monique Guignard, Department of Decision Science, The Wharton School, University of Pennsylvania.

DECISION SCIENCES CENTER

The 1986 report of the Committee to Review OR at MIT recommended an expansion of the scope of the ORC through creation of a Decision Sciences Center at the Institute. After two years of preliminary discussions and planning, this initiative gained momentum this year with three major faculty meetings that served to define the scope of the proposed center and work out issues of organization and planning. Faculty from the ORC as well as from other divisions within MIT organized a three-day retreat on Cape Cod in October 1988 to examine design alternatives for the proposed center and to discuss funding possibilities. During a follow-up one-day meeting held at Endicott House in January, faculty reported on progress and made further plans. A Vision Committee, consisting of senior faculty representing the various constituencies of the proposed Center, met regularly during the Spring Term to further define and refine program and funding issues and to initiate a proposal to the Administration for the inauguration of the Center. In June, a third faculty meeting was held to approve the proposal. We expect to present this proposal to the MIT Administration in the Summer of 1989.

The development of the Decision Sciences Center and of its research and academic programs is likely to dominate the ORC's agenda during the coming year.

SOME INDIVIDUAL ACCOMPLISHMENTS

A number of ORC-affiliated faculty and staff received noteworthy awards or "made the news" during 1988-89. We mention a few examples below:

Professor John D.C. Little, a former Director of the ORC and internationally known for his contributions to OR, management science, and marketing science, was appointed Institute Professor at MIT and was elected to the National Academy of Engineering. He was also named the first Philip M. Morse lecturer in operations research by the Operations Research Society of America (ORSA). (Philip Morse was the founder of the ORC as well as the founder and first President of ORSA.) Professor Thomas L. Magnanti, codirector of the ORC, served until May 1989 as President of ORSA. The Leaders for Manufacturing Program at MIT, of which he is also the codirector, received nation-wide attention in the media throughout the year. Professor Richard C. Larson's research on "the psychology of queues" was the subject of numerous national and local TV and radio programs and newspaper and magazine articles. Professors Dimitri Bertsekas and John Tsitsiklis published a major advanced text book on "Parallel and Distributed Computation," the first comprehensive and systematic treatment of the subject. A paper based on Professor Dimitris Bertsimas's PhD thesis work (completed in September 1988 under the direction of Amedeo R. Odoni) was awarded the George E. Nicholson Prize of ORSA, the top student award of the society. Marcia V. Chapman, the ORC's Assistant Director, was the recipient of the James Murphy Award for her contributions to the Institute and, in particular, to the quality of the student environment at the ORC. Professor Robert M. Freund received an Institute teaching award for his treatment of the introductory master's degree course in Operations Research in the School of Management. This award is based solely on student evaluations. Finally, Professors Arnold I. Barnett, Gabriel R. Bitran, Alvin W. Drake, Robert M. Freund, Steven C. Graves, John Hauser, Daniel J. Kleitman, Richard C. Larson, Thomas L. Magnanti, Amedeo R. Odoni, and James B. Orlin began or continued service as Editors or Area/Department Editors of the top professional journals in OR and management science.

THOMAS L. MAGNANTI
AMEDEO R. ODONI
Codirectors

Plasma Fusion Center

The Plasma Fusion Center (PFC) is recognized as one of the leading university research laboratories in the physics and engineering aspects of magnetic confinement fusion and plasma research. Its research programs produce significant results on several fronts: (a) the basic physics of energetic plasmas (plasma theory, RF heating, free electron lasers, development of high-temperature plasma diagnostics, and basic plasma experiments on the Versator tokamak), (b) major confinement results on the Alcator tokamaks, including pioneering investigations of the stability, heating, and confinement properties of plasmas at high densities, temperatures and magnetic fields, and (c) a broad program of fusion technology and engineering development that addresses problems in several areas (e.g., magnet systems, superconducting materials development, fusion environmental and safety studies, advanced millimeter-wave source development, and system studies of fusion reactor design, operation, and technology requirements). The Plasma Fusion Center technical programs are supported principally by the Department of Energy's Office of Fusion Energy. During the past year, the funding level has been approximately \$28 million. There are approximately 300 personnel associated with PFC research activities. These include: 33 faculty and senior academic staff, 73 graduate students and 15 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; 87 research scientists and engineers and 18 visiting scientists; 31 technical support personnel; and 39 administrative and support staff.

THE COLD FUSION EPISODE

Reports last spring of the observation of significant fusion occurring in palladium cathodes used in the electrolysis of heavy water set in motion an intense, collaborative research effort involving members of the PFC and affiliated laboratories. The initial disclosure was by the University of Utah scientists, Martin Fleischmann and B. Stanley Pons, and occurred in the Wall Street Journal on March 23, 1989. Two days later, scientists from the PFC and Department of Chemistry were attempting to reproduce the Utah phenomenon. The team was jointly led by Professor Ronald Parker, Director of the PFC, and Professor Mark Wrighton, Chairman of the Department of Chemistry. A few weeks later, members of the Departments of Nuclear Engineering and Materials Sciences and Engineering, led by Professor Ronald Ballinger, joined the effort, bringing the number of collaborators to approximately fifteen.

During the ten week period of intensive activity which followed, several other members of the MIT community participated on an ad-hoc basis. Special mention should be made of Professor Min Chen and colleagues from the Department of Physics who led an effort to produce muon-catalyzed fusion reactions in Pd-D_x and other hydrides, using a muon beam generated by the AGS at Brookhaven National Laboratory.

The elements of the Pons-Fleischmann experiment were disarmingly simple: a beaker filled with heavy water (D₂O), undergoing electrolysis as a result of a current passed between a palladium cathode and platinum anode. Since it was assumed that preparation of the cells, including specific treatment of the cathode, was important, the MIT group studied a large number of cells. In the initial experiments four cells, each having a different cathode size or preparation, were put into operation. A few weeks later, a second generation set of experiments was initiated, differing from the first mainly in degree of sophistication of the calorimetry and data acquisition techniques. Evidence of fusion activity was sought by several standard methods, including moderated BF₃ neutron counters, NaI(Tl) γ -ray detectors (for monitoring neutron capture reactions occurring in a nearby water bath), and mass spectroscopy including measurement of helium concentration in the palladium electrode. Contrary to the University of Utah reports, no evidence for fusion nor "excess heat," i.e., heat generation over that which could be accounted for by Joule heating of the electrolyte, was found.

In a separate study, a team led by Richard Petrasso simulated the neutron capture measurement reported by Pons and Fleischmann. In these experiments, the electrolysis cell was replaced by a calibrated PuBe source which emitted neutrons in the energy range produced by D-D fusion reactions. In comparing the resulting γ -ray spectrum, produced by neutron-capture reactions in a surrounding water bath, with that published by Pons and Fleischmann, important discrepancies were discovered. In particular, the Pons-Fleischmann spectrum had an unphysical resolution, the absence of structure resulting from Compton scattering in the NaI(Tl) crystal, and a peak intensity fifty times lower than it should have been, had their analysis been correct. Petrasso and co-workers concluded that neutron emission in the Pons-Fleischmann experiment, if it occurred at all, was orders of magnitude less than reported.

At the time of this writing, the claims of Pons and Fleischmann, and all others purporting to have produced significant quantities of heat by cold fusion, have been discredited. Although fusion researchers at the PFC were disappointed to find that a potential short-cut to fusion energy had turned into a blind alley, they were nevertheless heartened by the enthusiastic response that fusion elicited from the public during the cold fusion episode. This suggests that although progress in harnessing fusion energy is difficult and often frustratingly slow, the goal of achieving a superior energy technology will be well worth the struggle.

ALCATOR CONFINEMENT EXPERIMENTS

The primary objective of the Alcator experimental program is to develop the basic physics understanding of the stability, transport, and radiation properties of high-temperature tokamak plasmas at near-reactor conditions and to develop radio-frequency (RF) methods for heating and driving currents in plasmas at thermonuclear temperatures.

The major confinement activities at the Plasma Fusion Center now focus on the design, construction and preparation of the new tokamak facility, Alcator C-MOD, which will be sited in the east wing of the Nabisco Laboratory. Alcator C-MOD will provide valuable technical information regarding the operation of the high-field ignition experiment, CIT, and contribute to the advancement of tokamak concepts and physics understanding in areas such as ohmic- and auxiliary-heated confinement, stability, divertor-edge plasma behavior, control of plasma shape and profiles, and non-inductive current drive. The Alcator C-MOD major device fabrication is headed by David Gwinn as manager of machine construction. The Alcator C-MOD base program has been headed by Earl Marmor as physics coordinator during FY89 in the absence of Stephen Wolfe, who is spending a year on assignment at General Atomics. Within the base program there are several areas of major responsibility, including: radio-frequency heating (Miklos Porkolab); fueling and data acquisition and control (Martin Greenwald); diagnostics (Earl Marmor); divertor and edge plasma (Bruce Lipschultz); and theoretical analysis (Dieter Sigmar). Overall responsibility for all the activities of the Alcator group rests with the Toroidal Confinement Division Head, Ian Hutchinson.

In addition to the activities related to Alcator C-MOD, the Confinement Experiments Division has been active in collaborations with other fusion research groups both nationally and internationally.

Alcator C-MOD: The successes of the Alcator A and C tokamaks have demonstrated the value of the high-field, high-density, compact tokamak approach to plasma confinement. This approach is now embodied in the proposed national experiment, the Compact Ignition Tokamak (CIT), which offers the most promising and cost-effective means to explore fundamental physics issues associated with burning fusion plasmas. However, the step from Alcator C to CIT constitutes a large extrapolation in size, power, current, and other parameters. Therefore Alcator C-MOD provides a prudent and cost-effective way to develop an understanding at intermediate plasma conditions. It satisfies the need for further physics research on an experimental scale short of that required for fully ignited plasmas. The flexibility inherent in a moderate-scale facility can be used to explore different options and possibilities which the (necessarily) less flexible ignition experiment cannot explore.

In addition to its role as a prototype for CIT, Alcator C-MOD represents the next logical step in the high-field tokamak approach. Unlike its predecessor, Alcator C, it incorporates several modern tokamak features, such as a shaped, non-circular plasma cross-section, a poloidal divertor, and dominant auxiliary heating. These features will allow the investigation of high-density, high-temperature, ion- and electron-cyclotron-heated plasmas, with the goal of understanding the physics of RF heating, confinement, stability, impurity control, and fueling and shaping of high-performance tokamaks. Final approval for the construction of Alcator C-MOD was received in April 1987, and initial experimental operation is scheduled for the latter part of 1990.

The major radius of the Alcator C-MOD plasma will be approximately 67 cm (similar to Alcator C), and its minor midplane radius will be 21 cm. The plasma height will be up to 40 cm, with a typical elongation of 1.8. The toroidal field of 9 T is somewhat less than that in Alcator C, but the advanced shaping permits greatly increased plasma current, up to about 3 MA. Various innovative engineering features are incorporated in the design. The toroidal field magnet has sliding joints in its discrete coils; these permit the poloidal field coils to be mounted inside the toroidal field coils. The joints also reduce peak stresses in the magnets, transferring them to a massive, steel supporting structure that surrounds the machine. This design allows greatly improved access to the plasma for heating, diagnostics, and maintenance.

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Significant progress has been made in the construction of the Alcator C-MOD facility. Over seventy five percent of the hardware costs have now been committed for component fabrication by various industries. Major items include: \$1 million for the toroidal field magnets (Mitsubishi, Japan), \$0.3 million for the vacuum vessel (Meyer Tool, Illinois), \$1.8 million for the support structure (Thyssen, Federal Republic of Germany; Ladish, Wisconsin; Southern Bolt, Louisiana), \$1.6 million for the main power supplies (Robicon Corporation, Pennsylvania), \$0.2 million for RF power-supply modification (Uptegraff, Pennsylvania; Varian, Massachusetts), \$0.5 million for molybdenum tiles (Climax Specialty Metals, Connecticut), \$2.6 million for site modification and cell construction in the east wing of the Nabisco Laboratory (Vappi & Co., Cambridge), and \$1.1 million of MIT funds for the development of laboratory support space in the central section of the Nabisco Laboratory (Vappi & Co., Cambridge). The last two items represent a major improvement of the Nabisco Laboratory site for experimental plasma physics research.

The forged magnet superstructure has been delivered and a test assembly successfully completed. The lower part of the structure is now installed on its support legs in the experimental cell.

Power supplies have been delivered, on loan from Lawrence Livermore National Laboratory, and are undergoing refurbishment. Delivery of the vacuum vessel is expected in July 1989, when assembly and installation of the many components will begin.

Progress is continuing within the Alcator base program in the scientific preparation for experiments. This includes the detailed design and optimization of experimental plasma components such as divertors, first-wall components, and RF-wave launchers. A major effort is devoted to the development and implementation of diagnostics for determining properties of the plasma. These include diagnostics that will be used routinely for plasma-feedback control (a major scientific challenge), as well as state-of-the-art diagnostics to provide the most detailed measurements. These will allow a fuller description of plasma behavior and hence advance the predictive understanding of the fundamental properties of magnetically confined plasmas.

Graduate student involvement in the various aspects of the Alcator scientific program is extensive and diverse. Students are conducting thesis research and working as research assistants in areas such as: optimized plasma control, cryogenic hydrogen pellet injector development, diagnostic design, and magnet materials analysis.

Collaborative Programs: While Alcator C-MOD has been under construction, several of the scientific staff have been involved in experiments at other facilities. Funding from the Department of Energy, as well as other sources, has been available for this purpose, and the participation of experienced research staff in the wider international fusion program has been very productive. These collaborations help to establish good international relations as well as enhance the experience and productivity of the scientific staff.

Two C-MOD subsystems are being built in collaboration with fusion groups in the US and abroad. A hybrid computer for control of plasma position and shape is under joint development by the PFC and the Centre de Recherches en Physique des Plasmas (CRPP) of the École Polytechnique Federal de Lausanne. The CRPP has primary responsibility for hardware and the PFC for software. At the CRPP the computer will be used for plasma control for their TCV tokamak device. Software for data acquisition and analysis is being written, under PFC direction, by groups from the PFC, the Los Alamos National Laboratory (LANL) and the Istituto Gas Ionizzati (IGI) in Padua, Italy. This software, called MDS+, organizes all components of experimental data into a single coherent, hierarchical structure. LANL and IGI will employ the software for data from their reversed field pinch experiments, ZT-H and RFX respectively, The CRPP will also use the MDS+ software.

A particular effort in which the Plasma Fusion Center has played the lead role is the preparation of a lithium-pellet injector for use on the Tokamak Fusion Test Reactor (TFTR) facility at Princeton Plasma Physics Laboratory (PPPL). The pellets will be used for diagnostic purposes and fueling experiments, following up on the development of the injector and the success of initial experiments on Alcator C. The injector is installed on TFTR and PFC staff are stationed at Princeton. Experiments are expected to begin as soon as TFTR becomes operational again.

The Alcator C tokamak core has been relocated to Lawrence Livermore National Laboratory (LLNL), where experiments will be carried out to investigate electron cyclotron resonance heating (ECRH) using a high-power free electron laser (FEL). The recommissioned facility, called the Microwave Tokamak Experiment (MTX), began operation last year.

Scientists from the Confinement Experiments Division have participated in various capacities in the national CIT program. PFC researchers have made important contributions in the areas of RF-heating, alpha-particle physics, edge physics, ECH source development, and control systems. Scientists have also participated in various national workshops that have served to define and develop the CIT objectives and predicted performance. Looking further to the future, there is also increased scientific participation in the alpha-particle physics and RF-heating and current drive in the International Thermonuclear Experimental Reactor (ITER) design activity, which is a quadrupartite collaboration between the US, Europe, Japan, and the USSR.

APPLIED PLASMA PHYSICS RESEARCH

The primary objective of the Plasma Fusion Center Applied Plasma Physics Research Division, headed by Ronald Davidson, is to develop a basic experimental and theoretical understanding of plasma properties. Present applied plasma physics research activities include: experimental research on the Versator II tokamak (Miklos Porkolab and Stanley Luckhardt); experimental research on the Constance B quadrupole field facility (Donna Smatlak); fusion theory and computations (Abraham Bers, Bruno Coppi, Ronald Davidson, Thomas Dupree, Jeffrey Freidberg, Jay Kesner, Kim Molvig, and Dieter Sigmar); experimental research on chaos and the onset of turbulence (Paul Linsay); ionospheric plasma research (M. C. Lee and Jeffrey Freidberg); and space plasma research (Ronald Davidson and James Sullivan).

The progress made during the past year in selected applied plasma physics research areas is summarized below.

Versator Research Program: Versator-II is a medium-sized research tokamak (major radius $R = 40.5$ cm, minor radius $a = 13$ cm, toroidal magnetic field $B = 15$ kG) with primary emphasis on basic investigations of RF plasma heating and current drive. During the past year, the following experiments were carried out: (a) plasma start-up was demonstrated solely with RF techniques, namely combined electron cyclotron resonance heating and lower-hybrid current drive (without OH transformer); (b) a new electron cyclotron transmission (ECT) diagnostic was used to measure the non-thermal component of the electron energy distribution, and its confinement, in the presence of high-power RF fields; (c) a new dielectric-loaded waveguide array operating at 800 MHz was installed (dielectric constant $\epsilon = 80$) for purposes of testing lower-hybrid fast-wave launch and current drive in combination with 2.45 GHz slow-wave launch; and (d) using lower-hybrid current drive, plasmas with high values of poloidal beta ($\beta_p \approx 4$ and $\epsilon\beta_p \leq 1.3$) were established. It appears that the Versator II plasma may have entered the so-called "second-stability" regime, (for the first time in any tokamak), a potentially important result for future reactor applications. Although in the present experiments the pressure originates from the energetic tail electrons, the plasma remains "grossly" stable. Finer-scale stability properties are under study. In addition, a new laser-scattering system is being developed to measure the current profile during lower hybrid current drive experiments. Finally, design of a new, intermediate-scale tokamak facility, called Versator-Upgrade, has continued during the past year. Versator-Upgrade would provide graduate students with a modern tokamak facility for thesis research, as well as a flexible facility for investigating relevant tokamak physics issues during the next decade. The main characteristics of the device are: $R = 90$ cm, $a = 30$ cm, elongation 1.4-1.6, and toroidal magnetic field $B = 1.0$ -1.6 T, and the device would be located in the central section of the West Wing Experimental Cell. The purpose of the Versator-Upgrade program is to develop a flexible tokamak facility with major emphasis on transport and turbulence studies in the presence of current profile control in a shaped plasma with relatively high safety factor, $q(r)$, and high $\epsilon\beta_p$, where $\epsilon = a/R$ is the inverse aspect ratio.

Constance B is a quadrupole mirror device of moderate size in which high beta, hot electron plasmas are created using electron cyclotron resonance heating (ECRH). The major objective of the Constance program is to contribute to the basic physics understanding of the equilibrium, stability, and heating of hot electron plasmas. Investigations of ion transport in the quadrupole geometry and high-Z ion confinement are also fundamental parts of the Constance B research program. Initial experiments are also being carried out on the generation of silicon and metal plasmas for use in thin-film deposition for microelectronics.

During the past year, the studies of ion radial transport and multiply-charged ion confinement in Constance were completed. Ion radial transport was found to be anomalously high - ten times greater than that predicted by the classical and neoclassical theories for hydrogen, helium, and argon. A model of high-Z ion confinement was developed which is in good agreement with the experimentally measured confinement times and ion fluxes. This work suggests that radial transport may be limiting the performance of electron cyclotron resonance (ECR) ion sources used in accelerators and atomic physics experiments.

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Studies of the ECRH frequency scaling of ECR ion source performance are being carried out in collaboration with Spire Corporation. Experiments at 10.5 and 14 GHz were completed this year on Constance and experiments at 14, 18 and 28 GHz have been initiated.

In plasma theory and computations there has been substantial technical progress in several areas of research. The theoretical studies include: (a) electron heating and transport by ion cyclotron waves in tokamak plasmas; (b) strong absorption in mode conversion for ion heating; (c) investigations of two-dimensional kinetic plasma turbulence; (d) theory of MHD clumps; (e) development of an ultra-fast transport solver for applications to Alcator C-MOD, the Compact Ignition Tokamak (CIT), and the International Thermonuclear Experimental Reactor (ITER); (f) theory and implementation of magnetic probe diagnostics on non-circular tokamaks; (g) axisymmetric stability of non-circular tokamaks in the presence of resistive walls; (h) novel methods of achieving tokamak operation in the second region of stability; (i) relation of transport theory to empirical scaling laws in tokamaks; (j) effect of energetic, trapped, alpha particles on ballooning modes; (k) theory of alpha-particle effects in ignited tokamak plasmas; (l) theory of coherent electromagnetic wave generation by free electron lasers and cyclotron masers, including the development of advanced concepts, studies of chaos, and nonlinear models for saturation and efficiency enhancement.

Basic chaos experiments on three-frequency quasiperiodicity have been carried out to study the Ruelle-Takens (RT) model for the onset of turbulence. This model predicts that a nonlinear system with three oscillatory modes is structurally unstable and should become chaotic. One of the most interesting results was the observation of a "devil's cobweb" of interlaced periodic resonances, two-frequency quasiperiodic stripes, three-frequency quasiperiodic zones, and bands of chaos. The fractal structure inferred from this result indicates that the RT model is correct, but must be interpreted carefully. Even in a system with nonlinearities as large as the coupled relaxation oscillators investigated, the extent of chaotic behavior is quite small.

During the past year, research has continued on the development of experimental concepts and superconducting magnet designs for the Astronomy Magnet (ASTROMAG) facility planned for the Space Station Freedom. One such set of experiments would investigate fundamental space plasma processes in the "magnetosphere" of the ASTROMAG facility, which will act as a large magnetic obstacle moving rapidly through the ionosphere.

FUSION TECHNOLOGY AND ENGINEERING

The Plasma Fusion Center's Fusion Technology and Engineering Division, headed by Bruce Montgomery, provides critical engineering analysis for advanced design projects, and develops advanced superconducting and high-field copper magnet technology for the national fusion program. The areas of research during 1988-89 include: engineering design support for the Alcator C-MOD tokamak (Bruce Montgomery); studies of advanced poloidal field magnets for the Compact Ignition Tokamak (Richard Thome); studies of advanced magnetics for the International Tokamak Experimental Reactor program (Joel Schultz); concept development for improved magnetic divertors for tokamak and next-generation test reactors (Tien-Fang (Ted) Yang); development of internally-cooled, cabled superconductors for use in advanced fusion devices (Mitchell Hoenig); basic research on high-field, ductile superconductors (Simon Foner); and advanced magnet and conductor design in support of MHD and high energy physics projects (Peter Marston). Recent progress in selected technology and engineering areas is summarized below.

The Alcator C-MOD device, a new high-field tokamak under construction at MIT during 1987-1990, will test radio-frequency heating of the high-density plasmas that are characteristic of the conditions in a compact ignition tokamak. The Alcator C-MOD design features cryogenically-cooled magnets, a demountable toroidal field magnet, a single-piece vacuum vessel, and a poloidal divertor. The toroidal field coils for Alcator C-MOD incorporate sliding joints which require innovative engineering design and tests to ensure reliability. Assembly of the magnet began in May 1988.

The Compact Ignition Tokamak (CIT) is proposed as a national project, to be completed in 1997, and to be located at the Princeton Plasma Physics Laboratory. It will be a copper, high-field ignition device patterned after the Alcator series at MIT. Bruce Montgomery is serving as Senior Engineer, and Ronald Parker served as Project Physicist during 1987-88. Richard Thome is manager for the poloidal field system, and Daniel R. Cohn is head of special studies. The CIT will require special laminated inconel/copper plates for fabrication of the central solenoid and toroidal field coils. Practical bonding methods for these laminates are being developed as a major PFC program, with the help of Professors Frank McClintock and Regis Pelloux.

The International Thermonuclear Experimental Reactor (ITER) is a design and R&D activity which has grown out of a US/Soviet initiative at the Geneva Summit. The European Community and Japan are also participating in this three-year design and R&D effort. MIT is responsible for the U.S. poloidal field design. It is hoped that this activity will result in the decision to proceed with the construction of an international fusion test reactor in the 1990s.

The divertor development group has been active in developing innovative designs for particle control, modular tokamaks and magnetic systems. A novel system to actively recycle plasma ions back into the plasma core from the boundary by a set of ripple coils below the plasma column has been fabricated and installed on the TEXT tokamak at the University of Texas. The method would induce an influx of circulating particles which could reduce impurity generation and enhance beam heating.

The principal task involving the use of internally-cooled, cabled superconductors (ICCS) is the development of conductors for the two-meter outer-diameter prototype of the central solenoid (ohmic heating) coil for ITER. This task is multifaceted. It involves several collaborative efforts including: conductor sheath development in conjunction with Professor Ronald Ballinger; the development of a reliable commercial Nb₃Sn superconductor with US wire vendors, including research to develop optimized low-AC-loss conductor in quantities suitable for ITER use; and a joint program with the Naka Fusion Research Institute of the Japanese Atomic Energy Research Institute (JAERI) that will allow testing of a prototype double-pancake coil.

Basic research on high-field Nb₃Sn and Nb-Al superconductors using powder metallurgical techniques has continued. Focus has been on small-scale hydrostatic extrusion processing and on extending practical processing technologies. Exploration of mechanical alloying and rapid quenching has been continued for Nb-Al. Considerable activity has been underway during 1988-89 in collaboration with several research groups, evaluating the recently discovered high-temperature superconductors. DC fields up to 30 T, and pulsed fields up to 60 T are used for characterization.

The principal goal of MHD magnet design has been the development of a high-current conductor for large-scale MHD magnets based on the ICCS design. Conceptual designs of space-based magnet systems for both linear and disk multimegawatt MHD generators have also been developed.

FUSION SYSTEMS

The Plasma Fusion Center's Fusion Systems Division, headed by Daniel R. Cohn, investigates several aspects of fusion reactor conceptual design and develops advanced diagnostics. Research areas include: CIT design activities (Leslie Bromberg, Daniel R. Cohn); ITER design activities (Daniel R. Cohn, Leslie Bromberg); commercial reactor design studies (Leslie Bromberg, Daniel R. Cohn, and John E. C. Williams); safety and environmental studies (Mujid Kazimi); X-ray and gamma-ray diagnostic development (Richard Petrasso); and millimeter-wave and far-infrared laser diagnostic development (Paul Woskov). Selected technical advances are summarized below.

Compact Ignition Tokamak Design: There is active participation in a number of aspects of the design of CIT. Design variations are being evaluated including higher aspect ratio configurations and very high performance ohmic heating transformers. System studies are being carried out on electron cyclotron resonance heating, and an assessment of the economic tradeoff between the unit power of the gyrotron/source and its efficiency is being carried out. Burn dynamics and control are being studied with emphasis on use of variable, feedback-controlled auxiliary heating. Finally, work is being pursued on various ohmic heating (OH) transformer designs which are evolutionary improvements over the base line design.

International Thermonuclear Experimental Reactor (ITER) Design: A high-field, high-aspect-ratio ITER design variation is being evaluated. Potential advantages which have been identified in a preliminary analysis include reduced current drive requirements, decreased tritium consumption, reduced fusion power, and smaller machine size. Very substantial cost savings (on the order of 30 percent) may be possible.

Commercial Reactor Studies: The Plasma Fusion Center is participating in the national ARIES commercial reactor design. Activities include overall concept development and magnet design. A super-high-field concept that uses advanced low-temperature superconductors and advanced structural materials was proposed by the MIT group. The ARIES team has chosen this concept for the first reactor design to be developed by the project. Other high field concepts are also being investigated, including advanced fuel reactors.

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Safety and Environmental Studies: Potential safety advantages of fusion energy have been assessed through participation of Mujid Kazimi on the National Senior Committee on Environmental, Safety and Economic Aspects of Magnetic Fusion Energy. A comprehensive report of this committee, chaired by J. P. Holdren, has been written and serves as a major reference on these issues. Work on safety and environmental studies at MIT includes lithium fire modeling and analysis of the effects of magnet systems on safety.

X-Ray and Gamma-Ray Diagnostics: A gamma-ray diagnostic is being designed for CIT. Gamma rays at 16.7 MeV are produced by the $D + T \rightarrow He^5 + \gamma$ reaction. This diagnostic would be used for spatial and temporal determination of the alpha source function, a key element of burning plasmas. The gamma-ray diagnostic could also be used for the determination of D - He³ reaction rates in RF-heated plasmas by measuring the gammas produced in the $D + He^3 \rightarrow Li^5 + \gamma$ reaction. This diagnostic is also being evaluated for use in Alcator C-MOD, where it would be useful in measuring an energetic ³He tail produced by ion-cyclotron resonance heating.

Millimeter-Wave and Far-Infrared Laser Diagnostics: An effort is underway to develop a diagnostic to measure the velocity and spatial distributions of energetic ions using scattering of millimeter-wave gyrotron radiation. This measurement will provide information on fundamental aspects of thermal transport and plasma self-heating. A scattering system is being developed for use by PFC personnel on the TFTR tokamak at PPPL, possibly followed by implementation on the CIT device. Based on this concept, work has also been initiated on the JET tokamak.

Diagnostics for Space Studies : A new development/recovery system, the "Spin-Cast Diagnostic Package" is being designed for use around large orbiting vehicles. In addition, a concept has been developed for a laser radar system to measure particulates and debris around the Space Station. The laser system would provide information on particle size by use of a wide range of wavelengths.

COHERENT ELECTROMAGNETIC WAVE GENERATION

The primary objective of the Plasma Fusion Center's Coherent Electromagnetic Wave Generation Division, headed by Richard Temkin and George Bekefi, is to develop a basic experimental and theoretical understanding of coherent radiation generation by free electrons for wavelengths in a 1 micron to 1 cm wavelength range. Particular emphasis is placed on the development of gyrotrons (Kenneth Kreischer), free electron lasers, and novel radiation sources. A second area of research relates to theoretical studies of the basic equilibrium and stability properties of non-neutral plasmas and intense charged particle beams, with applications to high-current accelerators, coherent radiation generation, and nonneutral electron flow in high-voltage diodes (Ronald Davidson, Jonathan Wurtele). A third area of research is high power microwave sources including the relativistic magnetron (Shien-Chi Chen) and the cyclotron autoresonance maser (CARM), (Bruce Danly). A fourth area of research relates to basic theoretical and experimental investigations of laser-pumped, far-infrared molecular gas lasers, including studies of laser tuning and efficiency.

In the area of **gyrotron research**, gyrotrons with output powers in the 400-850 kW range at frequencies between 140 and 320 GHz and pulse lengths of three microseconds have been studied experimentally. These represent new records in output power and frequency for gyrotron devices. Such gyrotrons can be developed by industry into long-pulse or CW tubes for application to plasma heating. Work is now underway on extending the operating frequency to 280 GHz and the power level to one megawatt for eventual application to plasma heating on the Compact Ignition Tokamak (CIT). This research is in collaboration with Varian Associates, Palo Alto, CA, which will construct a novel electron gun for this program. A 12 T superconducting solenoid with a room temperature bore is also under construction for these experiments. The extension of gyrotron operation to higher frequency will require novel ideas for solving the problem of mode competition in highly overmoded gyrotron cavities. The role of electron beam quality in the saturation of the gyrotron interaction will also be investigated.

In addition to research on high power gyrotron oscillators, investigations are underway on two related, novel gyrotron devices. One device is a harmonic gyrotron. This device allows even higher frequency radiation to be achieved at kilowatt power levels. Frequencies of up to 500 GHz in microsecond operation have recently been obtained. The second device is the gyrotron backward wave oscillator. This is a promising source of tunable, kilowatt power level radiation at frequencies near 140 GHz. Research is also underway on novel antennas for launching high frequency gyrotron radiation into plasmas or transmission lines.

In the area of **free electron lasers (FELs)**, experimental studies have been carried out on the amplification, phase coherence, efficiency enhancement, beam quality and optical guiding in a free electron laser. These results contribute

to the basic understanding of this important new type of coherent radiation source. An outstanding issue in free electron laser research is the problem of optical guiding. One of the remarkable properties of the free electron laser, apart from its wavelength tunability and high efficiency, is the large phase shift which the resonant interaction induces in the amplified electromagnetic wave. Using the MIT free electron laser facility, the phenomenon of optical guiding has been demonstrated successfully. This is the first such experimental demonstration. The physics of prebunching in a free electron laser has been investigated using a concept developed some fifty years ago in the klystron amplifier. The dramatic increase due to prebunching in the free-electron-laser growth rate observed in recent experiments at MIT has been confirmed by computer simulations.

In addition to the above work, a new type of permanent magnet helical wiggler has been developed for free electron laser and gyrotron applications. The system consists of an assembly of staggered samarium-cobalt magnets. Innovative wiggler configurations are being investigated, including a circular wiggler in which a rotating electron beam is surrounded by an assembly of samarium-cobalt magnets. Very-short-period microwigglers for free-electron-laser applications are of considerable current interest. Besides their compactness, such systems have the advantage of producing higher frequency radiation with a given electron energy, or conversely, they reduce the electron energy required to access a given wavelength. Such a microwiggler has been constructed using the high-precision technology developed for the manufacture of multi-channel magnetic recording heads for space-borne applications.

A long-pulse relativistic magnetron microwave (3 GHz) source using a superconducting magnet has been designed and constructed and is now under test. The power supply for this experiment (700 kV, 750 A, 1 microsecond) has been built and tested. The goal of this research is to demonstrate long pulse operation of magnetrons at very high powers, up to 100 MW of output power. The magnetron will be phase locked using a 1 MW, tunable pulsed oscillator. The required injected power to phase lock and the degree of phase locking will be investigated.

The cyclotron autoresonance maser (CARM) is a novel, high power microwave source which appears capable of operation at high frequency, into the millimeter wave range. A long pulse, CARM oscillator/amplifier has been constructed using the same power supply as described above in the relativistic magnetron research program. Preliminary results have recently been obtained using a short pulse (20 ns) power supply which produces a 1.5 MV, 260 A electron beam. Amplification of an injected signal at 35 GHz was obtained. These results are very promising for developing the CARM as a high power source for powering accelerators or heating plasmas. Further research on short pulse sources of high power microwaves is planned using an induction linear accelerator loaned to MIT by Science Research Laboratory, Somerville, MA. Research on a relativistic klystron and a CARM is planned.

APPOINTMENTS AND PROMOTIONS

During the past year, there have been several important appointments and promotions in Plasma Fusion Center program areas.

Appointments include: William Burke (TRW Advanced Technology Division), appointed Electronics Engineer in the Toroidal Confinement Division; Valerie Censabella (Applied Reasoning, Inc.), appointed Divisional Administrator in the Toroidal Confinement Division; Chiping Chen (Stevens Institute of Technology), appointed Postdoctoral Associate in the Coherent Sources Division; John Dolan (City of Boston), appointed Assistant Fiscal Officer in the Fiscal Office; Jun Feng, (Massachusetts Institute of Technology), appointed Research Engineer, Fusion Technology and Engineering Division; Brian LaBombard (UCLA), appointed Experimental Research Scientist in the Toroidal Confinement Division; Thomas Painter (Massachusetts Institute of Technology), appointed Mechanical Engineer in the Fusion Technology and Engineering Division; Jeffrey Parany (Kaiser Systems), appointed Electrical Engineer in the Toroidal Confinement Division; Kathleen Powers (Massachusetts Institute of Technology), appointed Librarian in PFC Headquarters; Suzanne Rice (Kaman Sciences Corporation), appointed Mechanical Engineer in the Toroidal Confinement Division; and Bradford Smith (RCA), appointed Mechanical Engineer in the Fusion Technology and Engineering Division.

During the past year, promotions in the Plasma Fusion Center have included: Stephen Fairfax, promoted to Assistant Leader, Alcator C-MOD Engineering Group in the Toroidal Confinement Division; Marcel Gaudreau, promoted to Leader, Advanced Projects Group in the Fusion Technology and Engineering Division; Peter Hamilton, promoted to Associate Fiscal Officer, Fiscal Office; Min-Chang Lee, promoted to Leader, Ionospheric Plasma Research Group in the Applied Physics Research Division; and Donna Smatlak, promoted to Leader, Plasma-Materials Interaction Group in the Applied Physics Research Division.

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During the past year, the Plasma Fusion Center has also hosted many Visiting Scientists, Engineers, and Scholars in the various research programs. They are: Dr. Margalit Ben-Ari (Armament Development Authority, Israel), plasma theory and computations; Mr. Jerome Buzzi (Lycee-Luykanal, France), theoretical and computational physics; Dr. Franklin Chang-Diaz (NASA), plasma propulsion; Prof. John Davies (Clark University), theory of free electron lasers; Dr. R. Paul Drake (Lawrence Livermore National Laboratory), physics of laser plasma interactions; Mr. Giulio Flor (Istituto Gas Ionizzati, Italy), systems programming for data acquisitions; Dr. Henry Freund (Science Applications International Corporation), coherent radiation generation by free electron lasers; Dr. Suichiro Fuchino (Electronic Technical Laboratory, Japan), superconducting magnet technology; Dr. Hiroyuki Fujita, (University of Tokyo, Japan), acoustic emission technology; Dr. Daniel Goodman (Science Research Laboratory), induction linear accelerator; Dr. A.V. Gurevich (Lebedev Institute, USSR), radio wave-plasma interactions in the ionosphere; Dr. Gunter Haas (Max Planck Institut für Plasmaphysik, Federal Republic of Germany), novel pressure gauge at high magnetic fields; Dr. Frederic Hartemann (Thompson CSF, France), cyclotron autoresonance maser and free electron laser research; Dr. Satish Kandlikar (University of Rochester), superconducting magnet technology; Dr. William Kruer (Lawrence Livermore National Laboratory), physics of laser plasma interactions; Mr. Ulrich Lampen (Fachhochschule Technical University, Federal Republic of Germany), design and evaluation of superconductors; Dr. Guishi Luan (Institute of Plasma Physics, PRC), advanced tokamak magnet systems and plasma-wall interactions; Mr. Philip Marti (Asea Brown Boveri, Switzerland), cable-in-conduit conductors; Mr. Arnold Mobius (Karlsruhe Institute of Nuclear Physics, Federal Republic of Germany), high-power gyrotrons and quasi-optical couplers; Dr. Paul Moroz (Lebedev Institute, USSR), RF heating theory; Dr. R. Ernst Mueller (Max Planck Institut für Plasmaphysik, Federal Republic of Germany), novel pressure gauge at high magnetic fields; Dr. Jacek Myczkowski (MIT), theory of lattice gases to reduce fluid dynamics; Dr. Dwight Nicholson (University of Iowa), non-linear plasma physics; Dr. Yi-Kang Pu (SPIRE Corporation), electron cyclotron resonant ion source physics; Mr. Robert Randall (Supercon, Inc.), mechanical, material and metallurgical problems in superconductivity; Dr. Mitsunori Sato (National Research Institute for Metals, Japan), acoustic emission technology for monitoring of superconducting magnets; Dr. Frederick Seguin (American Science and Engineering), x-ray tomography on Constance; Dr. Abhijit Sen (Physical Research Laboratory, India), intense beam physics; Dr. Han S. Uhm (Naval Surface Weapons Center), theoretical studies of beam-plasma systems with intense self fields; Dr. Gerard Vichniac (BBN), theoretical plasma physics; Dr. Chun-Yi Wang (Zhejiang University, PRC), high frequency gyrotrons and novel concepts for free electron lasers; Dr. Reich Watterson (Science Research Laboratories), novel laser scattering diagnostics; Dr. Robert Witt (University of Wisconsin), stress analysis of structural support systems for the CIT poloidal field coils; Dr. Kongyi Xu (Chengdu Institute of Radio Engineering, PRC), high frequency gyrotrons; Dr. Xin-Zi Yao (Institute of Physics, PRC), diagnostic development; and Ms. Ge Zheng (Clark University), theory of free electron lasers.

GRADUATE DEGREES

During the past year, the following students graduated with theses in plasma fusion and related areas: Dawood Aized, S.M. in Mechanical Engineering; Sean Barnett, Ph.D. in Nuclear Engineering; Matthew Besen, S.M. in Mechanical Engineering; Frederick Cogswell, Ph.D. in Mechanical Engineering; James Crotinger, Ph.D. in Nuclear Engineering; Philip DiMascio, S.M. in Materials Science and Engineering; Peter Donis, S.M. in Nuclear Engineering; Steven Evangelides, Ph.D. in Physics; Daniel Goodman, Ph.D. in Physics; Susan Spira Hakkarainen, Ph.D. in Nuclear Engineering; Abdelhaq Hamza, Ph.D. in Physics; Ronald Miller, Ph.D. in Nuclear Engineering; Thomas Moran, Ph.D. in Physics; Thomas Painter, S.M. in Mechanical Engineering; Yuskel Parlatan, S.M. in Nuclear Engineering; Yi-Kang Pu, Ph.D. in Physics; Thomas Shepard, Ph.D. in Electrical Engineering and Computer Science; and Martin Zimmerman, S.M. in Nuclear Engineering.

We take this opportunity to wish these graduates success in their future professional endeavors.

RONALD R. PARKER
DIRECTOR
PLASMA FUSION CENTER

Research Laboratory of Electronics

Introduction

The Research Laboratory of Electronics (RLE), the Institute's oldest interdisciplinary research laboratory, was founded in 1946 as the natural evolution of the wartime Radiation Laboratory. Initially, RLE was formed to bring together interests in physics and electrical engineering to work on problems in electromagnetic radiation, circuits, and specialized vacuum tubes. Over the years, however, research interests in RLE have branched out into a number of directions, and in fact, several of these interests have grown to a size which has precipitated the formation of additional laboratories. Research within RLE is conducted by approximately 75 faculty members affiliated with the Departments of Electrical Engineering and Computer Science, Physics, Chemistry, Materials Science and Engineering, Aeronautics and Astronautics, Nuclear Engineering, and Linguistics. During the past year, approximately 250 graduate students and 100 undergraduates worked on research projects within RLE. Major support for this research is derived from the Joint Services Electronics Program (JSEP) of the Army, Navy, and Air Force; other Defense Department agencies; the Department of Energy (DOE); the National Science Foundation (NSF); the National Institutes of Health (NIH); and the National Aeronautics and Space Administration (NASA). In addition, many research projects are funded through industry and private foundations. Although RLE has a very heterogeneous character, its organization can be seen as comprising two major thrusts and seven smaller focus areas. One of the major thrusts is centered on electronics and optics, and the other is centered on language, speech, and hearing. Each of the seven smaller focus areas involves a few faculty, often with substantial overlaps in other areas of the laboratory.

ELECTRONICS AND OPTICS

Research in this major thrust area covers the entire gamut of electronics, from the production and characterization of electronic materials to processing techniques, device physics, high-performance integrated circuit design and simulation, and specialized system architectures. RLE's program in this area is highly interdisciplinary, drawing from expertise in physical chemistry, condensed matter physics, electronic materials, device design and characterization, processing innovation, optimal design of high-performance integrated circuits, and the exploration and search of architectural strategies for special purpose applications which include one-dimensional and two-dimensional image processing.

In order to achieve control over the epitaxial growth of materials at atomic layer resolutions, molecular beam and chemical beam epitaxial techniques are being employed by Professors Jesus del Alamo, Clifton Fonstad, and Leslie Kolodziejski. Professors del Alamo and Fonstad are concentrating on indium-based III-V heterostructures, and the high-speed devices that can be built from them. Indium-aluminum-arsenide/indium-gallium-arsenide (InAlAs/InGaAs) metal insulator-doped semiconductor field-effect transistors with very high extrinsic transconductance have been fabricated by Professor del Alamo. Large strain-induced electric fields in quantum wells on gallium arsenide as well as indium phosphide have been fabricated by Professor Fonstad in order to achieve more efficient optical modulators and guided-wave optical circuitry for long-wavelength optical communications and signal processing. Professor Kolodziejski has established a new chemical beam epitaxy facility that will be used to fabricate amphoterically doped zinc selenide (ZnSe) for blue light-emitting devices. In a complementary way, Professor Carl Thompson has developed a new procedure for producing epitaxial gallium arsenide films on silicon in a way that greatly improves crystal imperfection and electronic properties. In addition, he has quantitatively characterized the effects of microstructure on electron migration-induced failure in interconnect materials. This allows the prediction of the effect of microstructures on the reliability of interconnect lines with differing geometries. In addition to growing materials, many RLE projects involve fine-line processing techniques, as well as the basic scientific understanding of processing technologies. In Professor Henry Smith's Submicron Structures Laboratory, 50-nanometer-wide Schottky electrodes on gallium arsenide/gallium-aluminum arsenide have been fabricated, thus creating surface field-effect controlled quantum wells, where resonant tunnelling in a planar configuration has been observed for the first time. Also, a two-dimensional array of 4×10^8 quantum dots has been fabricated, providing a possible new implementation for very high-density memory. Principal Research Scientist John Melngailis has used two different focused ion beam machines to control doping profiles in the channel region of NMOS transistors, fabricate x-ray lithography masks with linewidths down to 50 nanometers in gold structures 250 nanometer thick, and perfected techniques for ion-induced deposition of gold lines with resistivities below 10 micro-ohm centimeters, thus successfully demonstrating the ability to accurately control the deposition of masked materials with high aspect ratio features. Although plasma etching is widely used in commercial silicon processing, it is poorly understood. During this period, Professor Sylvia Ceyer has shown that silicon can be efficiently etched by molecular beam techniques without using a high-energy plasma which causes radiation damage and other de-

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fects in the silicon. This understanding has been achieved through controlled experiments involving the reaction of fluorine (F_2) on a clean silicon surface within a special chamber designed to facilitate molecular beam interactions at surfaces. Professor Keith Nelson has shown how femtosecond optical pulses can be used to selectively excite and monitor optic phonon motions in crystalline solids. These results have very broad implications for optical control of crystalline structure and behavior, including optical fabrication and spectroscopy of highly distorted crystalline solids.

There is a strong connection between research in the materials area and investigations in the optics area. Much of Professor Fonstad's research in III-V heterostructures is devoted to photonic device applications, and Professor Kolodziejski has focused much of her research on zinc selenide (ZnSe) for use in blue diode lasers.

In the optics research area, Professor Hermann Haus has developed a new method of channel waveguide fabrication in gallium arsenide/gallium aluminum arsenide multiple quantum layers, with very low waveguide loss. In addition, new studies have shown that two-photon absorption plays a very important role in the nonlinear interaction in such waveguides. In a theoretical effort aimed at establishing a lower limit on noise in the detection of soliton pulses, a full treatment of the relevant quantum effects has been achieved. Professor Erich Ippen continues his research on the development and application of ultrahigh-speed optical technology. During the past year, a new mechanism called *additive pulse modelocking* (APM), used to generate femtosecond pulses, has made it possible to extend femtosecond methods to different lasers and new wavelengths. Formulation of this modelocking theory has been developed in collaboration with Professor Haus, and Professor James Fujimoto has already demonstrated its use in a titanium sapphire laser. This short-pulse laser technique provides a significant simplification for short-pulse femtosecond laser generation systems, as well as a significant cost reduction over conventional short-pulse approaches. Professor Fujimoto has also developed short-pulse surgical techniques using high-intensity picosecond laser pulses, and a study of biological effects of these pulses on tissue was used to establish a correlation between physical processes and tissue effects. Professor Peter Hagelstein has worked on the design and construction of a soft x-ray laser involving the application of fast, nonlinear optics technology to the problem of x-ray detection. He has also been studying the application of variational methods to relativistic Hartree-Fock atomic structure calculations, and has been working on a possible theoretical basis for recent claims of fusion effect observations at low temperature.

In condensed matter physics, several theoretical and experimental studies are coordinated to provide insight into a variety of novel states of matter. Professor Robert Birgeneau has studied surface reconstruction and surface roughening, and has recently exhibited novel reconstructions in the gold (100) surface, where the surface period becomes incommensurate with the bulk, while the surface itself simultaneously roughens and loses its long-range coherence. Professor John Joannopoulos' group has focused on developing a theoretical understanding of the electronic and structural properties of surfaces of solids. Recent accomplishments include the elucidation of the equilibrium properties of semiconductor surfaces under stress, the prediction of spontaneous formation of stress domains on reconstructed surfaces, and the identification of chemical and rehybridization reactions that are crucial to hetero-epitaxial growth. Professor Marc Kastner continues to study the properties of electron transport in one-dimensional silicon field-effect transistors. At low temperatures, the conductance oscillates periodically as a function of the density of electrons in a conducting channel, indicating that the channel electrons condense at low temperature from a gas into a crystalline state, which has never before been clearly demonstrated in a solid. In further studies of silicon field-effect transistors, Professor Patrick Lee has investigated the theory of resonant tunnelling through localized state, where he has demonstrated the important effect of Coulomb repulsion between two electrons on the same localized state for the first time. Professor A. Nihat Berker has focused on the calculation of finite-temperature phase diagrams for electronic systems and for semiconductor surfaces. Working with Professor Joannopoulos, he has combined finite temperature statistical mechanics with electronic energy calculations in a study of the silicon (100) surface. The stepping phase transitions of the surface, as a function of cut angle and temperature, have been derived showing remarkable agreement with experiments. Finally, Professor John Graybeal has examined the kinetic inductance of high-temperature superconducting phases of materials in order to better understand the superconducting phase boundary as a function of applied magnetic fields. Large grains of individual crystals of these materials have been obtained, thus enabling measurements of the desired boundaries, which will facilitate investigation of the underlying physics relevant to tunnel junctions and other potential device structures.

In the VLSI circuit design area, Professor John Wyatt and his collaborators have developed the requisite capability for construction of an integrated image acquisition circuit suitable for shape detection and velocity vector calculation. A new technology has been developed which combines charge-coupled devices (CCDs) with a basic CMOS process, and a new charge-coupled device image processing architecture has been realized in this technology. Furthermore, fundamental studies of resistive grid-based systems have been completed, together with a careful understanding of the stability criteria of these networks. Professor Srinivas Devadas has completed an efficient

exact algorithm for the state assignment of finite-state machines, and has also provided a precise classification of redundancies and don't-care conditions in interacting sequential circuits, thus facilitating synthesis procedures for irredundant, fully testable, interacting sequential circuits. Professor Jacob White has developed several numerical techniques for important problems in circuit and device design, including a highly efficient capacitance extraction algorithm which is linear in the number of tiles into which the conductor surfaces are discretized. He has also provided specialized simulation techniques using waveform relaxation for switched capacitor filters and switching power converters, and has provided new techniques for combining device and circuit simulation in an efficient way. Finally, Professor Jonathan Allen has extended grammatical techniques for verification of circuit style correctness to additional semantic tests which check for required properties of device size, charge sharing, and other electrical phenomena that cannot be readily represented in grammatical form. New and highly efficient techniques have also been developed for concisely representing the effects of waveform transitions in integrated circuits, which can be combined with macromodelling techniques to provide both accurate and efficient characterization of comprehensive integrated circuit systems.

LANGUAGE, SPEECH, AND HEARING

RLE has a large coordinated effort in speech, hearing, and the phonological aspect of language. This effort unites contributions ranging from auditory physiology to auditory psychophysics, speech communication, and linguistics; and increasingly takes an even broader viewpoint towards sensory communication in the large. Professor Kenneth Stevens continues to study the relationship between the underlying linguistic representation of an utterance and the surface acoustic manifestation of this abstraction. Models for the synthesis of fricative consonants have been produced, which accurately characterize how turbulence in the vocal tract gives rise to these sounds. Studies of the mechanisms of sound generation at the larynx have led to a quantitative specification of the individual differences in the sound source, and in particular, to the characteristics that distinguish female voices from male voices. This research on laryngeal mechanisms has also resulted in improved naturalness in the synthesis of different voices. Senior Research Scientist Joseph Perkell has characterized the motion of the articulators in determining vowel targets, as influenced by a combination of the communicative (acoustic) requirements of utterances and the constraints related to biomechanics and motor control. In addition, new and innovative facilities have been used for the study of vocal hyperfunction, which are providing insight as to the nature of the pathology associated with this condition. Finally, Dr. Perkell has studied subjects who have received cochlear implants, demonstrating that they are able to substantially reduce the amount of air expended per syllable in vocal production as a result of the implant procedure.

Research on sensory communication is being conducted by Professor Louis Braid, Senior Research Scientist Nathaniel Durlach, Principal Research Scientists William Rabinowitz, Charlotte Reed, and Patrick Zurek, and Research Scientists Xiao Dong Pang and Mandayam Srinivasan. New modelling efforts by these researchers have led to an improved understanding of the large gains in speech reception that often occur when highly degraded auditory input and lip reading are combined, together with a generalization of the additive law for information transfer from the case of independent variables to a much wider class of cases. Remarkably, it has been shown that the tactual sensory system is capable of essentially perfect speech reception when subjects are given long-term training with an appropriate tactual display.

In cooperation with the Eaton-Peabody Laboratories at the Massachusetts Eye & Ear Infirmary, long-range studies on the hearing mechanism are being pursued. The main emphasis is to understand auditory physiology by describing signals and mechanisms throughout the pathway from the external auditory meatus to the auditory cortex. Professor William Peake, together with Dr. John Rosowski, has been studying how sounds are amplified in the middle ear, and has discovered that at high frequencies, the mechanical advantage provided by the bones of the middle ear is complicated in that the axis of their rotation seems to move with changes in frequency. They have also used the fact that distortion products arising from nonlinear processes in the inner ear are reduced in abnormal ears, and hence, may provide a diagnostic technique for revealing these pathologies. The basis of these nonlinear effects is currently being studied in the simpler ear of the alligator lizard, where a model has been created to characterize the fact that distortion products grow to the third power of the stimulus under certain stimulus conditions. Dr. John Guinan has worked on the feedback pathways from the brainstem to the peripheral auditory system. He has shown that olivocochlear efferents depress basilar membrane motion, thus giving rise to threshold shifts of the auditory nerve fibers, and to adjustments in the effective range of the auditory system. He has also studied the stapedius muscle reflex, and shown that two populations of motor neurons are involved in these effects, each providing different aspects of efferent control of the middle ear. Professor Thomas Weiss has studied how sensory hair cells in the inner ear convey the mechanical stimulus to the transducers. Investigation of these processes in alligator lizard ears has shown that mechanical resonances are a dominant frequency-selective mechanism in this ear. Dr. Bertrand Delgutte has shown that nonlinear mechanical phenomena in the inner ear play a greater role in auditory masking than was previously thought, particularly for intense, low-frequency masking sounds. Continuation

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of these experiments in damaged ears may lead to improved designs for hearing aids. Dr. Donald Eddington is studying the biophysics and psychophysics of electrical stimulation of the peripheral auditory system in the context of an electrical cochlear prosthesis. Recent physical and psychophysical measurements have confirmed predictions made by a model of current spreading from the electrodes within the cochlea, thus facilitating both interpretation of experimental results and the design of new cochlear prostheses.

FOCUS AREAS

Atomic, Molecular, and Optical Physics

Professor Shaoul Ezekiel has developed a new technique for the measurement of inertial rotation based on a non-linear optical effect in a fiber resonator. This technique may be useful for other applications, such as reduction of the spectral width of an ordinary semiconductor laser by several orders of magnitude. Professor Daniel Kleppner has studied manifestations of chaos in quantum mechanical systems, including classical motion as a special case. Recently, it has been discovered that the spectrum of a highly excited atom in a magnetic field contains orderly progressions in a regime where the classical motion is chaotic; a finding contrary to the accepted notion of how quantum systems behave. Professor David Pritchard has developed a new type of mass spectrometer that can measure atomic masses with improvements in sensitivity by three orders of magnitude, using a novel detector comprised of superconducting electronics which allows measurements using only a single ion. These techniques should improve the relative precision of mass measurements to within 10^{-12} , allowing mass spectroscopy to address such fundamental problems as the neutrino rest mass, the Avogadro constant, and the binding energies of molecular ions and highly ionized atoms.

Plasma Physics

Professor George Bekefi has designed a novel cyclotron autoresonance maser, which is an interesting candidate to provide high-power, high-frequency drive for the next generation of particle accelerators. This is the first experimental test of the cyclotron autoresonance maser concept, even though extensive theoretical studies and numerical simulations have already been performed. Studies of radio-frequency fields that induce chaotic dynamics in the velocity space of the charged particles in a magnetized plasma by Professor Abraham Bers have shown that not only diffusion, but also drift of these particles across the magnetic field occurs, thus providing insight on the fundamental limits of radio-frequency heating in a confined plasma. In addition, he has completed a closed-form analysis of ion-cyclotron heating of plasmas, which is currently the most effective and promising way to achieve fusion temperatures in high-density plasmas. Professor Miklos Porkolab, using the Versator II medium-sized research tokamak, has studied a variety of phenomena in radio-frequency plasma heating and current drive, showing that the plasma in this tokamak may have entered the so-called "second stability regime" for the first time in any tokamak. This is a potentially important result for future reactor applications.

Radio Astronomy

Professor Bernard Burke has used the Very Large Array of the National Radio Astronomy Observatory to complete over 4,000 maps of radio sources, thus providing a vast new database for problems in extragalactic astronomy. One of the program's major objectives was to discover new examples of multiple quasar imaging by the gravitational lens effect, caused by intervening galaxies and clusters of galaxies. Several of these examples were obtained, comprising important new discoveries of these phenomena. Professor David Staelin has introduced new techniques to determine the altitude of precipitation through passive observations from overflying aircraft or spacecraft. Accuracies of one to two kilometers were obtained, providing the means to substantially improve satellite estimates of global precipitation.

Image Processing

The Advanced Television Research Program, under the direction of Professor William Schreiber, has developed a new technique to overcome the main limitations to picture quality that is set by transmission impairments, such as ghosts, noise, and interference. With the new scheme, the signal is encoded in a new way that provides increased robustness of the signal, but at the same time, provides much higher picture and sound quality within a given bandwidth. While such a transmission scheme implies a new receiver, versions of the scheme have been developed that allow a single receiver to receive both transmissions compatible with today's receivers as well as those emanating from the new scheme. Professor Donald Troxel is building a large multipurpose system for control, data collection, modelling, and scheduling of integrated circuit fabrication processes. By providing a flexible and interactive computing environment, circuit designers will be able to use both variations in fabrication processes as well as in circuit design, thus providing the basis for many new innovations that use custom VLSI processes.

Digital Signal Processing

Professors Alan Oppenheim and Jae Lim are developing a wide variety of new algorithms in several application areas. New theoretical results, coupled with source modelling that is particular to these applications, provide new and efficient coding and processing techniques, often coupled to special purpose computer architectures. In addition, they have introduced algorithms designed to provide both numerical and symbolic processing, leading to the notion of knowledge-based signal processing. Professor Bruce Musicus has developed a new class of iterative techniques to solve the problem of maximum likelihood estimation of relative time of arrival of an unknown stochastic signal at an array of receivers. He has also developed a new approach to building fault-tolerant signal processing architectures for special purpose applications in linear or homomorphic computation. New techniques have also been provided for efficient mapping of Fourier transform computations onto multiprocessor architectures, based on geometrical analyses of the underlying data flow graphs. Finally, highly automated strategies to map algorithms on architectures are being studied by providing mathematical optimization of architectures in terms of minimal chip area for each possible clock period. The optimization involved in this process has been converted into a linear programming problem, which can be solved at high speed for the optimal set of designs.

Electromagnetics

Professor Jin Au Kong has studied a wide variety of applications for electromagnetic wave theory, including micro-electronic integrated circuits, microstrip antennas, polarimetric microwave remote sensing, geophysical subsurface probing, and transient electromagnetic pulse propagation and coupling problems. Electromagnetic wave propagation in integrated circuits is studied with a combination of the method of characteristics and perturbational series under given circuit parameters, providing detailed analysis of signal rise time, distortion, and crosstalk. In addition, realistic theoretical models have been applied to several active and passive remote sensing schemes in order to detect plowed fields, atmospheric precipitation, vegetation, and snow fields.

Communications

Professor Jeffrey Shapiro has encountered new limiting effects in the characterization of squeezed states of light, thus possibly limiting the potential for greatly improved signal-to-noise ratio in measurement systems and in guided wave optical interconnection communication devices. In addition, several new improvements in the system theory for laser radar have permitted trade-off studies to be performed, thus expediting and improving the design of imaging laser radars for a variety of applications. Dr. Robert Rediker has developed new techniques to demonstrate the coherent combining of discrete semiconductor lasers which are fiber-coupled into an external cavity. In this way, high-power semiconductor lasers are achieved without the difficulties of dissipating large amounts of power in a small space. He has shown that the polarization effects that may be expected from the use of fibers should not interfere with this coherent combining, thus validating the proposed scheme, and raising the possibility of increasing the number of separate lasers from five to a much larger number.

In addition to the focus areas described above, several other research directions have been pursued within RLE. Professor Campbell Searle has studied speech processing in the peripheral auditory system from both the physiological and biochemistry viewpoints. He has now concluded that the peripheral filters are broad and not narrow at conversational speech levels, raising the possibility that the peripheral auditory system is adaptive across the variety of input acoustic levels. Professor Sow-Hsien Chen has used techniques of small-angle x-ray and neutron scattering, as well as photon correlation spectroscopy, to investigate the structure and phase transitions in macromolecular and supramolecular solutions. Recently, he made a direct measurement of the ion distribution around DNA molecules in solution by small-angle x-ray scattering. It is known that the precise conformation of a DNA molecule in solution is controlled to a large extent by the counter ion distribution around it. There are many theoretical calculations of this distribution, but this is the first time that a stringent experimental test of the theoretical calculations has been possible.

JONATHAN ALLEN

Sea Grant College Program

Congress established the Sea Grant College Program in 1966 to address the need for responsible development and management of marine resources. Existing programs of marine research and education at the nation's universities were recognized as important sources of information in this emerging field, and so a national program was created to provide them with financial support. The MIT Department of Ocean Engineering received one of the first grants in 1969 to develop a series of innovative texts. One year later, a larger "Sea Grant" was made to the Institute for a full research and education program. By 1976, MIT's Sea Grant contribution was so significant that the Institute was designated a Sea Grant College, the first private university to receive this recognition.

There are 29 Sea Grant Programs throughout the coastal and Great Lakes states. Funds are distributed among programs in a competing grant process by the National Oceanic and Atmospheric Administration through the national Office of Sea Grant. Each program is required to match its federal grant by one-half with contributions from non-federal sources including industry, state and local governments, universities, and private foundations. Congress established this matching provision to ensure that Sea Grant universities would be responsive to public and industry needs, and to encourage cooperation between those who do the research and those who use it. Sea Grant provides funds explicitly for technology transfer through both its research program and its mandate for advisory services and education.

Last year the Office of Sea Grant awarded MIT \$1.54 million; this was matched by \$1.3 million from industry, MIT, and the Commonwealth. MIT Sea Grant also received more than \$600,000 in related research support from several federal agencies. In all, these funds supported 17 faculty and 22 students from seven departments including Civil, Ocean, and Mechanical Engineering, Electrical Engineering and Computer Science, Chemical Engineering, Aeronautics and Astronautics, and Physics.

The direction of Sea Grant research at MIT is guided by both the unique resources of the Institute and the needs of the marine community. This research is currently focused on six theme areas: automation in the manufacture of marine systems; ocean engineering; unmanned underwater systems; technology development and management for ocean uses; living resource utilization, and coastal processes. Investigators from other Massachusetts universities participate in some of these research areas. Each of these areas is discussed below.

Computer-aided engineering has exciting applications in design, analysis, simulation, fabrication, and maintenance of marine systems. Funded initially through technology development, *automation in the manufacture of marine systems* has grown into a new theme area for MIT Sea Grant research. Basic research has led to a new mathematical method for representing shape so that the computation of intersections and blends is now much more efficient. This research has attracted additional support from the National Science Foundation and industry. Another project, supported by the Naval Sea Systems Command, attempts to accurately transfer geometric data between design and manufacturing systems. Projects supported by the Office of Naval Research include prediction of distortions of stiffened shells resulting from manufacturing processes like cutting, welding, and forming; and development of a new method to represent complex shapes through skeleton, or medial-axis, computations.

The 1988 Sea Grant Lecture/Seminar, "Automation in the Design and Manufacture of Large Marine Systems," provided a forum for the latest research in this burgeoning field. Naval architects, shipbuilders, computer engineers and other representatives of heavy industry were represented at the lecture that delved into ways to represent shape automatically, interrogate designs for performance, and build in tolerances to bridge the gap between idealized designs and fabrication capabilities. Highlighted by a keynote lecture on engineering education, the seminar also addressed methods for modeling fabrication processes, such as welding and cutting and for exploring potential uses of composite materials in marine systems.

As offshore structures move into deeper waters, industry and government require state-of-the-art technology to build structures that are both economical and safe. Toward this end, MIT Sea Grant research in *ocean engineering* includes: a project to use superconducting quantum interference devices for detecting and predicting corrosion in marine structures and a statistical study of extreme wave forces on offshore structures, information that will lead to more efficient engineering design for structures in hostile marine environments. The David Taylor Research Center in Bethesda, Md., provides funding to extend our theoretical understanding and numerical techniques for describing the performance of propellers. In particular, this research works to describe the effects of various flow irregularities, such as swirl, in front of or behind a propeller unit.

Sea Grant receives support from several U.S. Navy labs to study the operational behavior of marine ropes and cables. This research, prompted by public safety concerns and hazard prevention, has yielded valuable data on the pathology of synthetic rope deterioration and the effects of abrasion and tensile loading on rope strength. The projects seek to develop models to predict the breaking point and working lives of ropes in a variety of marine applications, including towing. In a separate but related program, Sea Grant receives Navy funds to analyze loads on tow ropes and cables in sea conditions where both the tug and tow are subject to large ranges of motion. Together, these projects will improve the safety and efficiency of both commercial and naval marine operations.

The development of new technologies and capabilities in *unmanned underwater systems* is a rich and diverse area of MIT Sea Grant research. A series of projects continue to develop control systems for autonomous vehicles using a novel hierarchical control (subsumption) architecture and a powerful new algorithm that incorporates both sliding and impedance control concepts. The goal of one project is to develop a roving vehicle that will investigate the dynamics of warm core rings and other large-scale ocean phenomena. Matching funds for research in this area have been provided by the Charles Stark Draper Laboratory Inc., the Henry L. and Grace Doherty Foundation, The H.A. Perry Foundation Inc., and the Massachusetts Centers of Excellence Corp.

MIT Sea Grant installed a containerized Underwater Work Systems Laboratory at the Boston National Historical Park's Charlestown Navy Yard. The lab was used as a test site for launching and field-testing underwater vehicles, including the remotely operated vehicle Seagrant I. Plans are under way on an interactive display for the site, which attracts about 1 million visitors annually.

Research into remotely operated vehicle and autonomous underwater vehicle activities has proven to be increasingly promising as a major future area for research. Given the multidisciplinary nature of research, MIT Sea Grant is particularly well-suited to coordinate efforts in this area. Jim Bellingham, a recent Ph.D. graduate from the MIT Department of Physics, was hired as a research engineer to coordinate Sea Grant's underwater vehicle research activities. Joining him was Thomas Consi, a post doctoral fellow with a Ph.D. in biology and insect behavior from Columbia University in New York. In addition, two Draper fellows are involved in working on underwater vehicle design.

Major in-kind initial support was provided by International Submarine Engineering Ltd. of Vancouver, British Columbia. ISE researchers invited the research engineer to spend six weeks with them while constructing MIT Sea Grant's autonomous underwater vehicle. ISE was very generous in providing technical support, various hardware and software, and general engineering guidance.

In the area of *technology development* Sea Grant has joined an interdepartmental research effort to understand and predict the formation and evolution of large-scale vortices. The importance of these phenomena in engineering and geophysics is tremendous. They appear to be a dominant influence in diverse areas ranging from oscillation of flexible structures to ocean current dynamics and beach erosion. This research combines analytical, numerical, and experimental methods. The goal of Sea Grant's research is to develop relatively simple rational models of these extremely complex phenomena by isolating their root causes and explaining large-scale vortices in terms of the stability properties of the time-average flow. The validity of the approach has been successfully tested in several applications, including transitions in jets and the interaction of ship wakes with the ocean surface. Other participants in this ambitious effort are the MIT Department of Ocean Engineering's Design Laboratory, the Department of Mechanical Engineering's Fluid Mechanics Laboratory, and the Plasma Fusion Center. Additional financial support has been received from Naval Sea Systems Command and the Office of Naval Research.

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Research in *living resource utilization* is directed toward developing technologies for producing high-value products from marine resources and advancing techniques to promote improved marine resource productivity. Researchers examined ways to control lipid oxidation in minced menhaden, a fatty, high-protein fish with potential for human consumption as surimi, and continued research into a novel biotechnology that seeks to improve fish reproduction in aquaculture systems through controlled release of implanted fish hormones. Researchers continued to investigate how biopolymers from marine sources might be used to develop controlled-release drugs, enzyme systems with locally controlled pH, and chitosan-based biosensors.

Interdisciplinary Sea Grant investigations of *coastal processes* seek to describe and model the behavior of currents, sediments, and chemical compounds. Projects during the past year included examining the response of silt-sized sediment to wave action, measuring the transport of pollutants from the Merrimack River to Massachusetts Bay, characterizing coastal colloids and studying the exchange of toxic organic compounds between sediments and the water column. Each of these projects represents a research program with broad applications that are specifically directed toward understanding and remediating the problems of Boston Harbor and Massachusetts Bay. Research support has also come from the cleanup program's leading consulting firm, Camp Dresser & McKee, and from the Massachusetts Water Resources Authority.

Further research into Boston Harbor is being conducted through the *Marine Center*, which provides marine industries and other government agencies a way to furnish funds to facilitate the transfer of technologies from MIT laboratories to their own. In addition, Sea Grant is advised of industry interests and needs in ocean research through Marine Center participants. The Marine Center, which has traditionally funded a handful of smaller projects, has shifted its focus to concentrate on fewer, larger projects. The first project of this kind will address coastal water quality, focusing on management of coastal algal blooms and contaminated sediments. Investigators will research areas of trace element regulation of nuisance algal blooms, such as red tides; sediment-water exchange of toxics; and modeling of water movement. Researchers also hope to employ an autonomous underwater vehicle to conduct some of the sediment sampling.

And, in their continued commitment to the harbor, MIT Sea Grant researchers maintain their leading role in establishing and working on statewide coordinating efforts for Boston Harbor and Massachusetts Bay.

To encourage the development of new research ideas, Sea Grant sponsors several seed projects annually. Last year a number of diverse projects included the development of fish oil supplements as adjunctive therapy and the continuance of a prison aquaculture project that developed technologies for raising both catfish and lettuce in a closed system and provided vocational training for inmates in those technologies. Several seed projects focused on student design experiences through the engineering of human-powered vehicles, including a submarine and a hydrofoil, and the study of the hydrodynamics of oars. Other seed projects developed sonar navigation techniques for an autonomous underwater vehicle. In an effort to understand the complexities of the Boston Harbor cleanup, one project chronicled the history of efforts since the settlement of Boston in 1630.

ADVISORY SERVICES

There are four parts to the MIT Sea Grant Advisory Services—the Marine Industry Collegium, the Center for Fisheries Engineering, the Massachusetts Marine Liaison Service, and Communications/Information Services.

The Sea Grant Collegium, the first industry collegium on campus, is the program's primary vehicle for technology transfer. The Collegium membership fee entitles companies to attend several technical workshops each year to meet with faculty and students and to review research in progress. Last year workshop topics included power systems for underwater vehicles, computer-aided design for marine systems, sensors for measuring ocean and coastal properties, water quality management, satellite image analysis and the development of marine biopolymers.

MIT Sea Grant's Center for Fisheries Engineering is recognized as an important regional resource for technical studies of fishing gear and vessel design. Using tow tanks at MIT and at the David Taylor Research Center, the Sea Grant Center tests scale-model trawl systems and conducts courses for fishermen. Courses have

been offered that demonstrate trawl gear from both coasts, including door behavior and the effects of the seabed on net behavior. In an effort to observe gear in use at sea, the Center has designed and developed a Towed Underwater Gear Observation System. Based on a series of successful trials, state marine fisheries staffs in Massachusetts and Maine will work with Sea Grant to use the vehicle in gear selectivity studies.

For the sixth year, the Massachusetts Marine Liaison Service (MMLS) coordinated Coastweeks, a statewide celebration that involved more than 75 organizations and attracted 24,000 participants. Events are designed to increase the public's appreciation for coastal resources and awareness of the need for good management. The MMLS personnel continued to serve as a liaison to advisory boards, including the Massachusetts Coastal Zone Management Program and the Citizen's Advisory Committee for the Massachusetts Bays Program. Currently, MMLS is creating a manual on how to handle water pollution problems. The sourcebook will include the legislation and agencies governing the Commonwealth's water resources.

Communications/Information Services added 35 publications to Sea Grant's report series. A complete collection of these volumes, since 1971 when the series was initiated, is housed in the Information Center, Sea Grant's small marine-related reference library; also on file are Sea Grant reports from the Woods Hole Oceanographic Institution and other members of the Sea Grant network nationwide. A computerized database allows for quick response to information requests from Sea Grant staff, MIT faculty, students and the public. More than 1,500 reports and other materials were distributed in 1988. Communications also issues press releases, handles media relations and produces the *Quarterly Report* newsletter, *Marine-Related Research at MIT* and the *Citizen's Guide to Sources for Marine and Coastal Information in Massachusetts*.

EDUCATION

The educational goals of Sea Grant are to provide learning opportunities to university students, professionals, and the public. Support for graduate students is included in almost every research project. In addition, the program continues to increase the number of grants awarded through the Undergraduate Research Opportunity Program (UROP). In 1988-89, 15 UROP awards were given in the fall semester, 16 in the spring, and 6 in the summer to undergraduates in the Departments of Civil, Ocean, and Mechanical Engineering; Electrical Engineering and Computer Science; Aeronautics and Astronautics; Physics; and Earth, Atmospheric and Planetary Science.

The Dean A. Horn Award was established in 1982 to honor the contributions of a former Sea Grant director. It is awarded annually to the marine-related UROP project that reflects Dr. Horn's high regard for significant innovative marine research projects carried out with competence and reported with clarity. In 1988, Lucas F. Ruecker was awarded the honor for his project that detailed the application of neural networks to predict the pathology of ropes. Ruecker is now a graduate student in electrical engineering. Freshman Gregory S. Bettinger, currently an electrical engineering major, was awarded an honorable mention for his analysis of salinity data from the North Atlantic ocean.

The seventh Annual Sea Grant Lecture/Seminar, "Automation in the Design and Manufacture of Large Marine Systems," was held in October 1988. More than 55 participants heard design and manufacturing experts summarize what is known and still unknown about the state of computer-aided design and manufacturing.

MIT continues its jointly sponsored program of continuing education for New England fishermen with the Massachusetts Maritime Academy and the Commonwealth of Massachusetts.

PROGRAM MANAGEMENT

The program director is Chryssostomos Chryssostomidis, professor in the Department of Ocean Engineering; associate research directors are Henrik Schmidt, associate professor in the Department of Ocean Engineering, and Keith D. Stolzenbach, associate professor in the Department of Civil Engineering. Norman Doelling is executive officer and oversees the operation of Sea Grant Advisory Services.

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New to the staff are Carolyn Levi, editor, and Leah McGavern, publications assistant. Karen Hartley has replaced Elizabeth Tayntor Gowell as communications manager, and John Moore has been promoted to manager of the Collegium. As noted above, Jim Bellingham and Thomas Consi were added to the underwater vehicles group.

MIT Sea Grant administers the Doherty Professorship, endowed by the Henry L. and Grace Doherty Foundation in 1973, for junior faculty at the Institute. In the spring of 1989, Andrew Whittle, assistant professor in civil engineering, was awarded the two-year chair to conduct research on soil behavior. Continuing to hold the appointment is Nicholas M. Patrikalakis, assistant professor of ocean engineering, for his work in surface-to-surface intersections, a type of mathematical research with applications in computer-aided design.

CHRYSSOSTOMOS CHRYSSOSTOMIDIS

Technology and Development Program

The Technology and Development Program's (TDP) primary objective is to provide a focus at MIT for research and education related to the role of science and technology in the socioeconomic growth of developing countries. The multi-disciplinary program is a mechanism to bring faculty and students at MIT together with faculty and staff in foreign universities, research institutions, and government organizations. Its more specific objectives are to:

- Promote an awareness of the relationship between science, technology, and development on the part of faculty and students at MIT;
- Provide a focal point for the activities of faculty, students, and visiting scholars interested in the field of technology and development;
- Assist the faculty, students, and staff of collaborating institutions in other countries to develop research and academic interests consistent with their national needs;
- Serve as a contact for interested organizations outside MIT (government, academic, private sector) to access the Institute's resources and its knowledge of developing countries—particularly of their socioeconomic and technological problems.

The TDP carries out its objectives through research, academic programs, and contacts with international and national organizations that are concerned with, or have an interest in, broad areas of technology and development. These activities are initiated on the basis of strong MIT faculty support and willingness to participate. The TDP does not undertake research projects which require large-scale, nonfaculty staffing, and all research activities are supervised by faculty members.

The TDP's experience has been that through cooperation among institutions in developed and developing countries, science and technology can be put to more productive use. As a result of such cooperation, both developing and developed countries can reach a better understanding of their own scientific and technological needs.

The Program Director is Professor Fred Moavenzadeh, George Macomber Professor of Construction Management in the Department of Civil Engineering. Professor Nazli Choucri of the Department of Political Science is the Program's Associate Director and Chairman of the Policy Committee. Committee Members are Professors Moavenzadeh, Daniel M. Holland of the Sloan School of Management, and Jack P. Ruina of the Department of Electrical Engineering.

The TDP-sponsored Middle East Program at MIT completed its third year with 10-12 graduate students participating in both the Fall and Spring Terms. The purpose of the program is to enable students with an interest in the Middle East to develop an expertise in the area in addition to their own academic field of specialization. The program examines the processes of socioeconomic change, technological development, political change, institutional development, capital flows, and business and investment patterns in the region. Two interdepartmental courses are offered by the program: Politics, Growth, and Development in the Middle East; and Technology, Business, and Public Policy in the Middle East. The program is under the direction

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of Professor Nazli Choucri, TDP Associate Director. Faculty members 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 participated in the program.

During the Fall Semester, Professor Choucri received a grant from the United States Institute of Peace for a two-year research project to examine patterns of conflict and transformations in the Middle East. The central thesis of the research is that changes in the capabilities of the states in the region affect foreign relations and the lines of conflict and contention. The project is expected to result in graduate level teaching materials and an international symposium which can serve to enhance the Middle East Program at MIT.

TDP faculty completed the design of the structure and content of a workshop which is to be given during the coming academic year. Entitled "Reconstruction in the Middle East: Challenges of Design and Development," the workshop is designed to provide an interdisciplinary orientation toward problems of reconstruction following violent conflicts. The concept of reconstruction is comprehensive in scope and includes reconstruction of society, form of governance, infrastructure, transportation, and related civil works as well as patterns of economic activity. The workshop will involve distinguished outside speakers in the presentation and discussion of historical cases of reconstruction and of issues and challenges in current Middle East reconstruction opportunities.

In addition to the workshop, Professors Gakenheimer, Lewcock, Porter, and Moavenzadeh are developing a graduate-level subject on reconstruction which will be offered next spring. This subject will focus on the influence of culture on reconstruction, strategies for the preservation and/or reconstruction of urban environments and spaces, and on the determination and analysis of supply-side issues (ranging from specific inputs such as manpower and construction materials on the one hand, to financing and administration on the other hand).

In the international arena, the TDP continued its negotiations with the Kuwait Institute for Scientific Research and Kuwait University to establish a major collaborative program to expedite development of the scientific and engineering capabilities of these two institutions. The proposed scope of activities includes joint research projects and supplementary educational activities such as workshops, faculty exchange, short courses, and fellowships. Research areas of potential interest include energy, petrochemicals, public works, electronics, and oceanography. During the past year, discussions and submission of preliminary proposals for similar large-scale collaborative programs have occurred with the University of Technology and University of Baghdad in Iraq, Ajman University College of Science and Technology in the United Arab Emirates, and the Olayan Foundation in Greece.

Early in June, TDP, together with ABT Associates and several Harvard faculty, submitted qualifications and a proposal to the United States Agency for International Development for a technical assistance project. The purpose of the project is to undertake pioneering research and help US AID establish a center of excellence in the areas of economic analyses of science and technology policies and of the impacts of technology transfer and technological change in developing countries. Currently TDP, in collaboration with Mr. Amine Gemayal (the former President of Lebanon and currently a visiting scholar at the Harvard Center for International Affairs), is developing "A Program on Conflict Resolution and Civil Reconstruction in Lebanon". The first stage of this program involves establishing an institutional framework and cooperative mechanisms with several universities in Lebanon which can provide both intellectual and managerial leadership to the future restoration of Lebanon.

FRED MOAVENZADEH

Technology Licensing Office

The primary goal of the Technology Licensing Office (TLO) is to facilitate the transfer of technology from M.I.T. to industry, and to benefit the public good through subsequent products. A secondary goal is to generate unrestricted income to support research and education at M.I.T. The TLO staff of fourteen, 7 professionals and 7 support personnel, are responsible for indentifying marketable technologies, managing their patenting and copyrighting process, finding licensees, and negotiating licenses.

In Fiscal Year (FY) 1989, the Technology Licensing Office (TLO) received over 300 new invention disclosures, continuing a trend of 37 percent per year compounded growth. We file patents on approximately one-half of the disclosures, with that percentage having declined slightly in the past four years (from a high of 64 percent in 1986).

Sixty-five new license agreements and options were signed in FY 1989 (not counting end-use software licenses). As in the past, the majority of agreements were with small-to-medium sized companies, but over a dozen were to large (Fortune 500) companies. All but three were to American companies. Four new companies were founded based on MIT licensed technology.

Cash royalties received during FY 1989 were \$3.1 million, up from \$2.7 million in FY 1988, in spite of a continuing decline in LISP royalties and the bankruptcy of a major LISP licensee. We also received new equity shares in two privately held companies, in partial lieu of royalties. In total, the value of MIT's shares of equity from TLO licenses increased \$1.3 million in FY 1989, and now totals \$4.8 million. One of the companies from which we received stock in FY 1988 went public in late FY 1989. MIT's shares of that company, previously valued at \$400,000, are now worth approximately \$850,000 on the open market.

A major issue is a rapid increase in patent legal expenses arising from two major causes: (i) the compounding growth of disclosures; and (ii) a considerably-higher-than-inflation increase in legal fees in the Boston area over the last several years.

Other accomplishments/events:

The TLO took over responsibility from the Microcomputer Center for X-Window end-use licensing in FY 1988. This year we arranged with outside vendors for duplicating and shipping, greatly reducing cost and burden on staff. Approximately 900 orders were filled; income was \$286,000. The Project Athena Network Services System (PANNS) will be added to this product line in early FY 1990.

A computerized data base and accounting system was installed in the office, allowing us to better manage case inventory (now totalling 2,500 active cases and over 300 active licenses) and office finances. With the rapid increase in licenses over the past three years, license maintenance is consuming an increasing fraction of staff time.

The "Intellectual Property Policy Guide" was completed with the help and approval of the Committee on Patents and Copyrights, and distributed to all faculty members and other interested parties. This includes MIT's conflict of interest policies as they apply to licensing and equity ownership by inventors.

One new licensing officer, Donna Baranski-Walker, MIT EE '81, was added to the staff, replacing Amy Porter who left early in the fiscal year. Ms. Baranski-Walker has allowed us to give significantly better coverage to Lincoln Laboratories. A financial administrator, Susan Imrie, was hired to manage the new database and accounting system.

JOHN T. PRESTON

Whitaker College of Health Sciences and Technology

INTRODUCTION

The Whitaker College has evolved into a major interdisciplinary academic and research entity at MIT. Since 1983, we have developed and incorporated areas of research and teaching that are pertinent to health and range from the fundamental to the applied.

Activity in the College is now divided among several interdisciplinary programs, and four departments. In addition to the Department of Brain and Cognitive Sciences and the Clinical Research Center, two exciting interdisciplinary program initiatives joined the Whitaker College effective July 1, 1988 - the Division of Toxicology and the Center for Environmental Health Sciences. Members of the Program in Toxicology are Dr. Gerald Wogan, Director and Professor; Dr. John Essigmann, Associate Professor; Dr. Steven Tannenbaum, Professor; Dr. William Thilly, Professor; and Dr. Helmut Zarbl, Assistant Professor. Dr. William Thilly is also the Director of 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

Under the direction of Dr. Robert Mann, Director of Biomedical Engineering Programs in the College, we have focused our efforts in two areas: (1) biological and medical imaging including radiological sciences and (2) medicinal chemistry and drug delivery systems.

BIOLOGICAL AND MEDICAL IMAGING

The Whitaker College Biomedical Imaging Laboratory was established last summer with the completion of necessary structural modifications and the arrival of new advanced equipment. The laboratory has as its focus the acquisition, processing, and display of medical and physiological images from a wide variety of imaging modalities and sources. Although the research programs are still in their infancy, we believe that we are in a position to define new areas of application for imaging technology. Specifically, the laboratory has the potential to make significant contributions in fields such as radiation therapy for cancer treatment, orthopedics and biomechanics, and cardiology. The research activity involves faculty and students from many departments including the Departments of Nuclear Engineering, Mechanical Engineering, Brain and Cognitive Sciences, the Division of Health Sciences and Technology and the National Magnet Laboratory. We have also initiated promising collaborations with colleagues at the Massachusetts General Hospital and other areas hospitals. The facility is designed around a cluster of networked Sun-4 computers with a TAAC-1 image processing accelerator. Images may be acquired remotely and transferred to the facility by the network or by magnetic tape. Through the volumetric analysis of three-dimensional data sets derived from magnetic resonance imaging (MRI), computed tomography (CT), and positron emission tomography (PET) data, our work will lead to new ways of visualizing and quantifying anatomical and physiological information. Under the direction of Professor Derek Rowell of the Department of Mechanical Engineering, research activities over the past year in the laboratory include:

Development of Advanced Image Processing and Rendering Techniques. The facility is investigating and developing new methods which will serve as an aid in the interpretation of images. This work involves image segmentation, enhancement and feature extraction in two-dimensional images, and methods of rendering and display of three-dimensional structures. The goal is to provide a "user-friendly" environment for the processing and display of images from a variety of diagnostic sources.

Prof. D. Rowell, Prof. V. Wedeen

MRI Imaging of Turbulent Flow. New MRI image acquisition techniques and processing methods are being investigated to display the statistics of turbulent flow in human arteries and veins.

Prof. V. Wedeen

Phase Enhancement of MRI Flow Images. The use of MRI phase information is being studied. This should improve the present (magnitude-based) methods of flow visualization.

Prof. V. Wedeen, Mr. J. Grisham

The Imaging of Muscle/Ligament Insertions around the Human Knee. Volumetric CT images are being used to map muscle and ligament insertions around the knee and to correlate the measured positions with local bone density as determined from CT measurements. The results of the study will be used in kinematic and loading models of the human knee.

Prof. D. Rowell, Dr. H. Ault, Mr. M. Murphy

The Biomechanical Role of the Meniscus in the Knee. The goal of this research is to provide a better understanding of the function of the menisci in load-bearing and lubrication of the knee. Photogrammetric imaging methods are being developed to track displacement and distortions of the meniscus as loads are applied. In addition, an attempt is being made to use MRI images to construct a three-dimensional model of the meniscus *in-vivo* so that its motion may be studied under movement. This work will be combined with a finite-element model of the knee for estimation of the stress distribution under axial loads.

Prof. D. Rowell, Mr. G. Brown

Three Dimensional Finite-Element Mesh Generation from Medical Images. Biomechanical stress/loading analyses using finite-element methods require accurate description of the skeletal structure and a means of dividing up the bone into a "mesh" of small three-dimensional elements. The manual generation of a three-dimensional mesh from images of a biological structure is a very time consuming task and cannot currently be handled by automated mesh generators. In this project a new mesh generator, designed specifically for bony structures, has been developed and is being tested. The system takes as its input a set of contours extracted from a set of images and develops a mesh that can be used by finite-element analysis software packages.

Prof. D. Rowell, Mr. S. Levesque

Imaging of Muscular/Skeletal Structures. Techniques for rendering and display of the muscle and bone structure are being developed. The objective is to provide a tool for visualizing the movement of individual muscles around a joint during movement. This project involves the development of new imaging methods that can be applied to moving objects, methods of processing CT and MRI images to extract the relevant muscle and bone structures, and rendering and display methods.

Prof. D. Rowell, Prof. V. Wedeen

The Three-Dimensional Display of PET Data. Positron Emission Tomography images are conventionally displayed as a sequence of slices. In this investigation, methods of visualizing and displaying such data in a single three-dimensional structure are being developed. Investigations include studies of time-gated images of oxygen uptake in a beating animal heart and oxygen uptake in a stroke-damaged brain. To our knowledge, this type of image display has not previously been used with PET data.

Prof. D. Rowell, Prof. G. Brownell, Dr. A. Brownell

Monte-Carlo Simulation of Neutron and Photon Transport for Dosimetric Calculation for Boron Neutron Capture Therapy. A sophisticated Monte-Carlo simulation package is being used to provide the necessary parameters for the design of a neutron delivery and patient irradiation facility.

Dr. J. Yanch, Mr. X. Zhou

RADIOLOGICAL SCIENCES

Dr. Gordon L. Brownell, who holds a primary appointment in the Department of Nuclear Engineering, has been a principal force in the development of education and research in radiological sciences in the College. He and several students are studying the distribution of boron compounds in biological tissues. Techniques include autoradiography, scanning ion and electronic beam microscopy. In related study, a collaboration to develop an epithermal neutron source using a new type of ion accelerator has been established with a small local company. A proposal for funding support of this project was accepted by the Department of Energy this spring.

The doctoral program in Radiological Sciences is managed jointly by the College and the Department of Nuclear Engineering. Candidates are admitted to the Department of Nuclear Engineering and pursue their academic and research objectives in one of four specialty areas: medical, diagnostic, and therapeutic technology; radiation biophysics, radiopharmaceutical chemistry; or biological and medical imaging. Research is conducted at several Harvard-affiliated hospitals, the Harvard School of Public Health, as well as at MIT in relevant departments, the National Magnet Laboratory and in the College's Image Processing Laboratory. Twenty-two students were enrolled this year. Plans to submit an institutional training grant in support of this program are underway.

The search for new faculty in an area related to Radiological Sciences and Imaging, has resulted in the appointment of Dr. Jacquelyn Yanch as Assistant Professor, effective July 1, 1989. Dr. Yanch's primary appointment will be in the Department of Nuclear Engineering, with a secondary joint appointment in the Whitaker College.

MEDICINAL CHEMISTRY AND CONTROLLED DRUG DELIVERY SYSTEMS

Dr. Robert Langer's work is at the interface of biotechnology, materials science, and bioengineering. A major focus has been on the creation and application of polymers to deliver drugs continuously at controlled rates for prolonged periods of time. This work was launched when he developed the first controlled release system for the delivery of large molecules such as proteins. This approach is especially important for the successful utilization of many genetically engineered drugs which are normally rapidly destroyed by the body. The technique has now been employed by his laboratory and by others for long term (>100 days) delivery of insulin, DNA, chemotactic substances, growth factors and enzymes.

Work is in progress in several areas, including: 1) investigating the mechanism of release from polymeric delivery systems with concomitant microstructural analysis and mathematical modeling; 2) studying applications of these systems including the development of effective long-term delivery systems for insulin, interferon, growth hormones and vaccines; 3) developing controlled release systems that can be magnetically, ultrasonically, or enzymatically triggered to increase release rates; 4) synthesizing new biodegradable polymeric delivery systems which will ultimately be absorbed by the body (one of these polymer systems is now being used at sixteen major medical centers to treat patients with normally fatal brain cancer); 5) creating new approaches for delivering drugs across complex barriers in the body such as the blood brain-barrier and the skin; and 6) synthesizing new biodegradable polymer scaffolds to be used in mammalian cell transports for engineering new organs and tissues e.g. the liver and nerves.

Prof. Langer's interest in drug delivery systems has extended to situations where useful drugs may also be toxic. In such cases, it would be useful to have a selective drug removal system. One example is the use of extracorporeal medical machines (e.g., artificial kidney, blood oxygenator) which require the addition of anticoagulants (e.g. heparin) to the blood to prevent coagulation due to exposure to a foreign surface. However, heparin is responsible for more deaths than any other drug because, upon reentry to the body, it causes serious complications. Prof. Langer and his laboratory have proposed that these problems may be circumvented by designing a reactor containing immobilized heparinase, which converts heparin to harmless substances. Approaches for covalently attaching the enzyme to biocompatible support materials,

reactor design, and the safety and efficacy of the resultant reactor are being studied. Other removal systems studied this year include the enzymatic removal of bilirubin in the case of neonatal jaundice and the enzymatic removal of cholesterol.

Finally, Prof. Langer is working on the development of drugs that specifically inhibit the process of neovascularization without interfering with existing blood vessels. Neovascularization is critical to the progression of several diseases, including cancer, retinopathy, rheumatoid arthritis and psoriasis. A substance from cartilage that directly inhibits capillary proliferation, thereby restricting tumor growth, has already been isolated and partially purified. This substance is now being tested against different animal tumors and will also be further purified for characterization and possible synthesis. New assays (*in vitro*) are being explored to facilitate the purification procedure. Methods to increase the yield of this inhibitor are also being explored.

Prof. Langer, who holds a secondary appointment in the Whitaker College which houses his major laboratories, has a primary appointment in the Department of Chemical Engineering.

PROGRAM IN HEALTH POLICY MANAGEMENT

The Health Policy and Management Program is projected to terminate in June, 1990, with the completion of the degree programs of the six students currently enrolled. All have passed their qualifying examinations and are working on their dissertations. Subjects of dissertation research include the impact of AIDS on the blood supply; technologic change and demand for hospital care; risk assessment and perception in health care; and the influence of biotechnology upon the pharmaceutical industry.

Last summer, the faculty and students offered an MIT Special Summer Program entitled "Managing the Quality of Health Care." The course was very well received by thirty six participants. There are plans underway to offer the course again during the summer session of 1989.

FACULTY AND STAFF

Dr. Emilio Bizzi, Eugene McDermott Professor in the Brain Sciences and Human Behavior, resigned as Director of Whitaker College, effective 1 March 1989. Professor Bizzi had led the College from the conceptual stage to its present state of vigor and excellence. His very success, however, made it difficult for him to discharge his then responsibilities and also serve as Director. Fortunately, he has agreed to continue as Chairman of the Department of Brain and Cognitive Sciences.

Professor Robert W. Mann, Whitaker Professor of Biomedical Engineering in the Department of Mechanical Engineering, had worked closely with Professor Bizzi in the development of bioengineering programs in the College since July 1, 1986. Professor Mann resigned as Director of Biomedical Engineering Programs in the College concurrently with the resignation of Professor Bizzi. We are grateful for the guidance which he has provided.

Professor Robert Langer has been named the Walter F. Enz Lecturer at the University of Kansas. He also received the Founder's Award for Outstanding Research by the Controlled Release Society, The Creative Polymer Chemistry Award by the American Chemical Society, and was cited as having the Outstanding Patent in the State of Massachusetts which was one of the twenty outstanding patents in the U.S. this year. Prof. Langer was also elected to the Institute of Medicine of the National Academy of Sciences this year.

OTHER CHANGES

Following recommendations for approval by the Committee on Graduate School Policy and by vote of the Faculty, the Corporation approved a new degree program in Toxicology to be granted through the new Division in the Whitaker College.

Effective March 1, 1989, the Executive Committee endorsed a change in the name of the College so that it is now the Whitaker College of Health Sciences and Technolgy.

**KENNETH A. SMITH
DIRECTOR**

Department of Brain and Cognitive Sciences

INTRODUCTION

Research in the Department of Brain and Cognitive Sciences integrates diverse approaches to the understanding of brain functions. The Department provides a focus for collaborative efforts across disciplines at the Institute and offers an opportunity for comprehensive and multidisciplinary training of new scientists. The faculty now includes 29 primary appointments, three joint secondary appointments, a large research staff, and 40 postdoctoral fellows.

In the Department of Brain and Cognitive Sciences, there are four areas of research: neurobiology, computational neuroscience, systems neuroscience, and cognitive science. Research in these areas is conducted by the faculty with their students and postdoctoral fellows. The faculty's research effort is amplified by collaborative arrangements with other departments and laboratories such as the Department of Biology, the Department of Linguistics and Philosophy, the Departments of Mechanical and Electrical Engineering, the Artificial Intelligence Laboratory, the Research Laboratory of Electronics, and the Media Arts and Sciences Center. These collaborative efforts have expanded in the last year.

RESEARCH

Neurobiology

Faculty members in this area are involved in a variety of studies ranging from the development of neuronal morphology and connectivity to the cellular and molecular basis of behavior and neurochemistry.

With respect to the development of the nervous system, the faculty's efforts are proceeding along two lines. One line of research is focused on understanding how the diversity and specificity of individual neurons arise from the undifferentiated embryonal cells and how neurons are assembled at the right time and place during development to generate a properly functioning nervous system. The other line is directed at understanding the role of molecules such as the proteoglycans that are involved in the growth and the guidance of axons in the brain.

With respect to the molecular basis of behavior, research efforts using the *Drosophila* system are focused on understanding the biochemical mechanisms underlying learning and memory. The interesting finding is that *Drosophila* mutants which fail to learn or which forget rapidly have identifiable lesions in the second-messenger systems. It is conceivable that these molecular processes underlying learning and memory are conserved across species from flies to humans. Such a finding would have clear implications for mental health.

With respect to neurochemistry and neurotransmitters, a number of studies have focused on such important transmitters as acetylcholine, serotonin, and dopamine. Among the important recent discoveries achieved by the faculty of the Department of Brain and Cognitive Sciences, I would like to mention the finding that there are specific factors enhancing the vulnerability of dopamine-containing neurons in the brains of patients affected by Parkinson's disease. This insight may lead to new therapeutic strategies relevant to the treatment of this devastating disease.

Systems Neuroscience

Research in this area is focused on understanding the visual, the auditory, and the motor systems.

Studies of the visual system, which range from investigations of early visual processes to the study of higher visual functions, are conducted by a number of faculty members. With respect to early processing of visual information, our faculty has focused on the role of the parallel channels that originate from specific neurons of the retina. Because selective blocking of single channels is now possible, a series of physiological and psychophysical studies have been conducted. These studies

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are aimed at assessing which basic visual functions (such as color, brightness, contrast sensitivity, perception of movement, and stereopsis) are altered by the block.

With respect to higher visual functions, our faculty has investigated the role of the cortical areas involved in transferring visual information into the motor system. They have identified an important cortical area in the parietal lobe, responsible for transforming visual signals coded in retinal coordinates to coordinates of the desired location of the eyes in the head.

Other cortical areas involved in the processing of visual motion are also being investigated. Finally, the plasticity of the cortical neuronal machinery is being tested through an experimental rerouting of visual fibers into the auditory centers. The preliminary results indicate that the reinnervated "auditory" center can process visual information.

In the auditory system, progress has been made in tracing the pathway connecting the peripheral sensory cells to the analyzing centers in the brain.

The motor system is also an area of intense investigation. The focus of these studies is to understand the neural and computational processes underlying arm trajectory planning and execution.

Computational Neuroscience

Faculty members have focused on the study of information-processing in the area of vision and motor control. Basic research activity during the past year has addressed issues ranging from studies of object recognition to computational models of visual motion perception, machine-vision projects, and motor learning. In addition, computational work has been directed at the characterization of biophysical mechanisms subserving the detection of motion by cells in the retina.

Cognition

Cognitive science is the study of intelligent biological systems as exemplified principally by the human brain. Research in the Department is focused on psycholinguistics, visual perception and visual psychophysics, reasoning, and human conceptual development. MIT's Center for Cognitive Science brings together this research and related work in linguistics, philosophy of mind, and computer science. Research on neurologically impaired patients, another important area of investigation, is conducted at the Clinical Research Center.

One new appointment in the Cognitive Sciences was made this year. Dr. Maryellen C. MacDonald will join the Department in September 1989. Dr. MacDonald is an expert in the fields of language acquisition, adult psycholinguistics, and human memory.

EDUCATION

Graduate

As the restructured graduate program becomes increasingly well known in the United States and abroad, there has been a rise in the number and quality of applications for admission. There were 171 applications for September 1989, from which a class of 13 entering students has been chosen.

There were 54 graduate students enrolled as of September 1988, a small increase over the previous year. Students received a number of competitive awards from the Whitaker College, the Whitaker Health Sciences Fund, the National Science Foundation, and the Office of Naval Research. The Department continues to receive predoctoral support from three NIH training grants. Without exception, students who graduated during the academic year have found excellent postdoctoral positions, junior faculty positions, or industrial research positions.

Undergraduate

The Department continues to play several roles in undergraduate education. It is the home department for the undergraduate major in Cognitive Science, in which 42 students were enrolled as of September 1988. In addition, several members of the Department's faculty participate in the Program in Psychology, offering undergraduate subjects that fulfill Humanities and Social Science requirements, including the concentration requirement. With widespread faculty participation in UROP, there are many opportunities for undergraduates to become involved in laboratory research projects in the various fields represented in the Department.

Other Activities

The Department has continued to offer lunch-time seminars featuring speakers of national and international renown. These seminars have consistently been popular and well received. In addition, members of the Department acted as co-chairpersons and speakers at the Fall Neurobiotechnology Conference sponsored by Whitaker College and the Industrial Liaison Program.

Faculty and Staff

Members of the faculty have been extremely productive and have received recognition by the Institute and outside foundations.

Dr. Edward Adelson was elected Fellow of the Optical Society of America.

Dr. Christopher Atkeson was awarded the Alfred P. Sloan Foundation Fellowship and the Keck Chair in Biomedical Science.

Dr. Ann Graybiel was elected Honorary Member of the Royal Academy of Medicine and Surgery of Seville.

Dr. Richard Held was appointed Member of the Aerospace Medical Advisory Committee of NASA.

Dr. Arthur Lander was awarded the Packard Foundation Fellowship and the Edward J. Poitras Chair in Human Biology and Experimental Medicine.

Dr. Hermann Steller was awarded the Searle Scholar and the Pew Scholar Awards.

Dr. Mriganka Sur received the Graduate Student Council Teaching Award for 1989.

Dr. Shimon Ullman received the Weizmann Institute Levison Award in Mathematics, 1988.

Dr. Jeremy Wolfe received the Class of 1922 Chair and the Baker Memorial Award for Excellence in Undergraduate Teaching.

Dr. Richard Wurtman was awarded the International Prize for Modern Nutrition, 1989.

EMILIO BIZZI, M. D.
Chairman

Center for Environmental Health Sciences

MAJOR ADVANCES

Two laboratories within the Center have made important advances in the past year which will drive the work of the Center for the next decade.

Professor Steven Tannenbaum's group has devised analytical means to measure reaction products of the polycyclic aromatic hydrocarbons directly on hemoglobin in ordinary human blood samples. This group of compounds contain many human mutagens ubiquitous in nature which reach humans via the air (soot) or food (broiling). Understanding of human risk may now be based on actual knowledge of human exposure to these noxious chemicals.

Professor William Thilly's group has after ten years of developmental effort devised analytical means to observe the set of all mutants in a DNA sequence as they occur in human tissues or any other organism using DNA for its genetic code. Since it is known that each chemical mutagen produces a specific mutational spectrum this new technology opens the door to rational determination of which environmental chemicals do or do not cause genetic changes in human tissues.

Summary of Center Objectives and Philosophy

The Center for Environmental Health Sciences aims to bring together parts of established disciplines at MIT which are, or should be, focused on discovering which ordinary inter-actions between humans and chemicals, biologicals or radiation, are in fact harmful to health. It is a basic tenet of our field that given accurate knowledge of the nature and extent of harm associated with exposures to identified substances, individuals may make informed choices for themselves; societies make choices for the health of the general public, particularly the young.

The faculty, students, and research staff of MIT's Center for Environmental Health Sciences are focused on discovery of the agents in our environment responsible for genetic changes in humans. Our focus is based on our perception of the public health needs. Genetic disease causing severe physical or mental impairment of our newborns approaches 2% and fills nearly half of the beds in our pediatric hospitals. Human cancers require several genetic changes (mutations) inherited or occurring within the organ from which the tumor arises. It also seems clear that atherosclerosis - a colonization of arterial walls with descendants of a single aberrant ancestor - requires specific mutations.

Given that genetic change is required to cause these diseases, we have undertaken the research programs necessary to discover the general causes of genetic change. We will also be required to find the causes of very specific genetic changes causing particular diseases. In this effort, we are linked to the earliest efforts in genetics. Indeed, the concept of a gene as a quantum unit of life was to a great extent clarified by Muller's observation that x-rays caused stable changes (mutations) in fruit flies. One of the principal intellects in the establishment of quantitative biology, Max Delbruck used the early dose-response relationship between fruit fly mutation and x-radiation in order to calculate (correctly it seems) that cosmic rays were not a significant contributor to the rate of spontaneous genetic change (in fruit flies).

After the identification of x-rays as mutagens, ultraviolet light and then reactive chemicals were found to be able to cause genetic changes in fruit flies, bacteria, and bacterial viruses. We came to see the world we live in as a complex mixture of chemicals, radiation, and bits of genetic material impacting on humans through the everyday processes of eating, drinking, and breathing. Smoking, narcotic and alcohol abuse, and medicinal treatment are a part of that reality. Exposure can occur for a small number of people in a particular occupation or to millions of people sharing the air in a particular city.

The Center is a consortium of faculty with special knowledge of food chemistry, combustion, incineration and air pollution, hazardous waste storage and environmental movement in water supplies, toxicologists and analytical chemists. We have identified the chemicals principally responsible for causing the genetic changes observed when bacteria or human cells are exposed to certain food or soot. We have mustered the collective will and developed the necessary technology to discover by iterative experimentation the principal causes of the mutagenicity of any complex mixture. This form of collaborative research and its contribution to knowledge has been one of our Center's most important accomplishments. We have directed attention away from the search for "most active mutagen" and focused it on the search for "most important mutagen": the product of environmental concentration and specific mutagenic activity is used to set both research and remediation priorities.

A good example of the application of this concept has been the identification of the most important mutagens from fossil-fuel combustion products generated by a variety of devices which burn fossil fuels and the kinds and amounts of chemicals in the emissions. We have also conducted bacterial and human cell mutation assays on the products. This comprehensive approach has provided the data necessary to understand the chemical and physical mechanisms by which mutagens are synthesized in combustors, the chemical identification of the mutagens of concern, and the definition of the conditions required for their destruction.

The Center has built well-established combustion research efforts in the Chemical engineering Department involving Professors Beer, Howard, Longwell, Sarofim and Tester. A large number of combustion facilities are available ranging from low-pressure small flames used to identify key combustion intermediates to a well-instrumented pilot-scale three megawatt thermal combustion facility. Fuels studied include natural gas, petroleum distillates, coal, shale-oil, and solvent-refined coal, as well as pure compounds such as benzene and ethylene which are used to unravel the complex mechanisms of the pyrosynthesis of mutagens.

Of course, every concept has its limitations. Our discoveries of important mutagens and carcinogens in ordinary environmental mixtures were limited in practical public health value by the fact that our laboratory test systems - bacteria, human cells, and rodents - were not people. We know that when a chemical enters the body, a complex cascade of series and parallel chemical reactions ensues. The reactions lead to innocuous excretion or potentially mutagenic reaction with the genetic material, DNA. The number of catalysts - enzymes - involved in these cascades is large enough and evolutionary time so great that the dynamics of these cascades in tissues of different species are, in general, non-identical and frequently grossly different. Within a particular human the dynamics of this cascade - usually called drug metabolism - varies significantly among the various organs and the cell types within organs. This diversity prevents confident extrapolation of the genetic effects of a chemical from one species to another or from one tissue to another. Furthermore, the field of pharmacogenetics has established the fact that among non-inbred species, such as humans, the range of drug metabolism capability is so large that one cannot meaningfully speak of "human" drug metabolizing unless one has characterized a

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sufficiently large number of individuals. This fact is well known in pharmaceutical development in which adverse effects of drugs on several percent of patients has been linked to marked deviation from average behavior in drug metabolism.

A second complex cascade of biological reactions separates the DNA reaction products from the stable genetic change itself. This cascade is known as "DNA repair" and consists of enzymes cutting out abnormal reaction products and restoring the DNA to its original sequence. It is the failure of the DNA repair system to act before DNA replication is required or the introduction of the wrong DNA sequence in the repair process that ultimately leads to hereditary change after a cell is treated with a mutagen. As in the case of drug metabolism, the processes of DNA repair involve many different genes; diversity among species is the rule and variation among tissues and humans in the population occurs to an important extent.

The substantial variations among species and among humans in drug metabolism and DNA repair obliges us to conceive of an approach which does not depend on either species extrapolation or the statistical mean of human populations. Put simply, a person is expected to suffer significant genetic damage from the environmental agents to which he or she exposed if, and only if, his or her particular pattern of drug metabolism and DNA repair permits such damage. Since we eat, drink, and breathe tens of thousands of potential mutagens each day, there exists no real means to use non-human systems with confidence in predicting absolute or relative human genetic risk arising from exposure to a particular compound.

Now that this hard truth has been faced, Center faculty are in a position to work together to build a new intellectual paradigm and to develop the technology to apply it to human studies.

Our new paradigm consists of three questions:

(1) What are the chemicals which enter the human body which can themselves or through metabolites react with genetic material?

We accept as axiomatic that chemicals that do not enter the human body will not cause genetic harm. If we knew which chemicals were reacting with people's DNA, we could focus on them to discover if they are causing significant genetic damage.

Unfortunately, we do not yet have analytical means to identify and measure the reaction products with DNA in convenient and safe human samples such as one to ten milliliters of blood.

However, chemical reactions with DNA are mimicked to a reasonable extent by reactions with the blood proteins such as hemoglobin. The quantity of hemoglobin adducts has been sufficient to allow Professor Tannenbaum's group to develop a new technology to measure any of the series of amino or nitro-aromatic compounds. This work has provided us with the first quantitative picture of a whole class of environmental chemicals in people. Present work focuses on developing the means to measure hemoglobin adducts of aromatic amines and the polycyclic aromatic hydrocarbons.

The next major step needed is to be able to measure and identify hemoglobin adducts of unknown structure. Professor Klaus Biemann's projects are aimed at this goal. The process involves fundamental changes in the hardware of mass spectrometers.

In related work, Professor Gerald Wogan's lab is exploring means of interfacing separation technology with the mass spectrometric developments so that DNA adducts may themselves be directly measured and identified.

(2) Of the chemicals found in ordinary humans, which, if any, cause significant amounts of genetic change?

Given knowledge of the set of chemicals bound to a particular person's hemoglobin, it does not seem unreasonable to hypothesize that one or a few of these chemicals have been the principle causes of mutations in the same body compartment. Thus, the analysis of chemical adducts "accuses" suspects for the analytical geneticists to interrogate.

The interrogation involves applying a process under development for obtaining the mutational spectrum of white blood cells from the individual studied for each accused chemical. The mutational spectrum is the distribution of all mutations in a particular DNA sequence with regard to kind and position of mutation. The mutational spectrum from the donor sample could be compared to the spectra induced by the "accused" chemicals. The process is similar to using fingerprints in identification. When a "match" is made, there would be strong circumstantial evidence that the chemical found in the donor's blood proteins had been responsible for a significant amount of genetic change in the donor's blood cells.

An important point is that each person serves as his or her own control in such studies. The large interpersonal variations expected in drug metabolism and DNA repair should not, therefore, interfere with this proposed diagnostic process.

(3) Which chemicals are significantly contributing to the genetic changes leading to human disease as cancer?

Certain mutations specific both for kind and position are now known to be necessary for genetic activation of the ras cancer genes in humans and experimental animals. Because recent work has shown that a small fraction of DNA of human atherosclerotic plaque can cause a form of neoplastic transformation of rodent cells, it seems reasonable to consider the possibility that there exists one or more genes that follow analogous genetic pathways in this important disease state.

The work of Professor Gerald Wogan's laboratory has focused on the set of such mutations appearing in liver tumors in rats after aflatoxin treatment. Further knowledge of the set of similar, specifically-required genetic changes in all human tissues at risk will be required to devise means to identify the exogenous chemical mutagens that might, in the case of studying individual humans, induce these specific onco-mutations.

Professor Helmut Zarbl is studying the network of physiologic effects of oncogene mutation, and aims to uncover additional loci which must be considered at risk for mutation by environmental chemicals. A key set of his experiments now in progress aims at discovering whether carcinogens causing organ specific tumors with specific ras mutations act by causing the mutation or selecting for cells in which the specific mutation already exists.

It follows from this discussion that the set of chemicals causing most of the total genetic changes in a particular human need not necessarily include the chemicals that induce tissue-specific tumors or atherosclerotic plaque. Indeed, the very existence of mutational spectra teaches us that we must examine the effect of a chemical mutagen within the context of a particular DNA sequence. Further, other evidence indicates that, within a tissue, one will have to consider variables such as the degree of transcription of a gene or the cell's proliferative state in defining the mutational spectrum for any mutagen.

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The group of interacting scientists who consider these variables are organized in a program aiming at dissecting the molecular steps in mutagenesis. This group, with faculty in MIT's Division of Toxicology and Departments of Biology and Chemistry, Harvard University's Department of Biochemistry and Molecular Biology and the School of Public Health, considers the molecular pathways of genetic change in bacteria, yeast, rodent, and human cells.

Of particular interest is the ability of Professor Essigmann's laboratory to synthesize DNA segments containing known chemical reaction products in specific positions. Using these constructs, it is possible to unambiguously determine the fate of an adducted nucleotide in the process of mutation.

Surely this is an exciting time for analytical chemistry, genetics, and oncology as the means to carry our studies to the human body are within our reach.

Toward Human Population Studies

Progress in proteins or DNA and analytical genetics of human tissue samples now leads us to epidemiological studies to find out what chemicals are present and which ones are causing genetic damage in ordinary citizens.

To prepare the way for intelligent application of the new technology, the faculty of the Parsons Laboratory for Water Resources and Hydrogeology have begun a major study of the fate and transport of chemicals in the nearby Aberjona River Basin. Already in progress is a chemical reconnaissance in the Basin, characterizing the nature and amounts of chemicals in local ground and surface waters. The Aberjona Basin is home to some 50,000 people, including many faculty and research staff and their families, and has been since precolonial times the site of industries such as tanning and bulk chemical production that involved release or storage of large amounts of chemicals now known to have the potential to cause genetic damage. Professors Bras, Chisholm, Gelhar, Harleman, Hemond, McLaughlin and Morel have proposed a comprehensive program of integrated research projects in the Basin.

This Aberjona Basin Study will involve a large portion of the Department of Civil Engineering's Parsons Laboratory faculty. The need for careful macro-and microscale modelling of mass transfer within the basin is required for both water-and air-borne chemicals. Working out the population exposure patterns will take some few years, which is consonant with our expectation of time needed to be ready to use the direct human measurement technology.

Of course, knowledge of air and water exposure must be factored with food and drug exposure to create a complete picture of human exposure. We hope to bring our methods to bear on population studies in our own communities without prejudice as to what we may find. Other epidemiological efforts less catholic in scope are already in progress. Studies of smokers, persons exposed to high concentrations of therapeutic drugs or markedly high levels of dietary mycotoxins are coordinated with studies in experimental animals and cell cultures.

The process of developing a new paradigm for human studies requires special care to be sure that early observations are not inappropriately interpreted. We foresee a period in which the best of us must remain determinedly agnostic, focusing always on our responsibility to discover what interactions between us and our environment are in fact harmful to health.

Clinical Research Center

The Clinical Research Center (CRC) was established in 1964, with grant support from the National Institutes of Health (NIH), to provide a facility in which Massachusetts Institute of Technology (MIT) investigators and their collaborators could apply the Institute's expertise in basic biochemical and biophysical mechanisms to the analysis of normal and pathologic processes in humans. Although MIT did not, and still does not administer a regular teaching hospital to which its CRC might be attached, it was anticipated that a large enough number of qualified physicians from MIT's faculty and staff would become involved in the CRC's activities in expanding the kind of research that MIT-based investigators could explore.

For most of its history, the CRC was administratively located within the Department of Nutrition and Food Science, (or later, Applied Biological Sciences), and the primary research interest of most of its principal investigators was nutrition/metabolism. These activities included determining human protein requirements under various conditions (for example, high physical activity); exploring the utility of artificial protein sources; and characterizing circadian rhythms in, and meal effects on, plasma amino acid patterns. Research in this general area remains a CRC commitment, particularly the focus on amino acid metabolism. However, from its inception, the CRC also supported an active program in the clinical neurosciences, starting with the still-ongoing studies on the cognitive and sensorimotor consequences of brain trauma, directed initially by Professor Hans-Teuber, and now by Professor Suzanne Corkin. In 1981 the CRC became an independent entity within the School of Science, and two years ago it was incorporated within the Whitaker College, reporting to the Director of Whitaker College and Associate Provost, Professor Kenneth Smith who is also the Principal Investigator of the CRC's NIH grant.

Scientists and physicians authorized to carry out research protocols using the CRC's facilities, once these protocols have been approved by MIT's Committee on the Use of Experimental Subjects (COUHES) and the CRC Advisory Committee, include: professors; research scientists who work exclusively at MIT; and those with primary appointments in local medical institutions whose research interests overlap extensively with those of MIT investigators.

The CRC is administered by a Director, (Professor Richard J. Wurtman), an Associate Director (Dr. William Abend); three Assistant Directors (Drs. Benjamin Caballero, William H. Dietz, and Naomi K. Fukagawa); and Dr. Elaine Shiang who acts as the liaison between the Medical Department and the CRC. The CRC Core Laboratory and its Gas Chromatograph Mass Spectrometry facility are directed by Dr. Robert Hoerr. The Assistant Directors are all young physicians who have completed residency training in medical specialties (medicine; neurology; psychiatry; and pediatrics) and have also had advanced research training, usually leading to a Ph.D. degree. Their appointment as Assistant Director allows them both to cultivate their own research interests at an important early stage in their career and to serve the CRC (for example, facilitating the conduct of clinical research by other MIT faculty who lack medical training).

The CRC Advisory Committee, consisting of 19 voting members plus six non-voting members of the CRC's Program Staff, reports to the Principal Investigator, Dr. Kenneth Smith. The Committee meets monthly and evaluates protocols for their scientific quality, experimental design, statistical analysis and potential risk to human subjects. Protocols may be approved contingent on minor modifications; deferred; or disapproved.

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The Advisory Committee also sets general policies and reviews the operations of the CRC. It has not previously been necessary for the Advisory Committee to prioritize protocols, since - with careful scheduling - adequate resources have usually been available to implement all approved protocols. However, such prioritization may become necessary in the future.

For the past year utilization at the CRC totaled 655 inpatient days and there were a total of 2,274 visits to the CRC's outpatient facilities.

The CRC has continued to provide postdoctoral training for physicians who are participating in fellowship programs at MIT. These physicians have utilized the CRC's facilities to initiate research protocols and to participate in ongoing projects supervised by senior investigators and faculty. There have been two graduate students and 12 post-doctoral fellows appointed at the CRC, (through the Department of Brain and Cognitive Science, the Whitaker College and the MIT Harvard Division of Health Science and Technology) during 1988-89. At the undergraduate level five Undergraduate Research Opportunities Program (UROP) students participated in clinical research projects with physician preceptors and faculty supervisors.

In February, 1989, the CRC sponsored a half-day symposium on "School Lunch in the Context of Cardiovascular Disease", speakers were R.Curtis Ellison, M.D. and Tami Cline, R.D. Their topics were "The Clinical Perspective" and "The School and Student Perspective", respectively.

Joint Commission on the Accreditation of Healthcare Organizations

Until 1988 CRC Certification by the Joint Commission on the Accreditation of Healthcare Organizations (JCAHO) had not been required, inasmuch as the CRC did not provide diagnosis of, nor treatments for, its subjects' illnesses. Furthermore, JCAHO certification was not needed in order for the CRC to obtain a Massachusetts license. Moreover, MIT's CRC - unlike other NIH funded Clinical Research Centers - was not part of a hospital. Therefore, it did not automatically derive JCAHO accreditation from that type of association. In January 1988, in response to an NIH mandate, the CRC started the process of applying for JCAHO certification, and was notified soon thereafter that, given the scope of its activities, the JCAHO chose to examine it as an ambulatory care facility. After a nine-month period of preparation, during which By-laws were written, a new committee structure established, and formal quality assurance mechanisms developed, the CRC was examined on June 20-21, 1988. Based on that examination, it was awarded accreditation as an ambulatory care unit in September, 1988.

Medical Department Merger

Since the JCAHO accreditation as an ambulatory care facility was not considered adequate by the GCRC branch of the National Institutes of Health in view of evolving guidelines requiring that NIH-funded CRC's be certified as hospitals, discussions were initiated with MIT's Medical Department leading, on October 3, 1989, to the decision of all parties that the CRC be incorporated within that department, - which is a JCAHO-accredited hospital. This incorporation took place on February 1, 1989, and has conferred JCAHO accreditation as a hospital upon the CRC. Association with the Medical Department will allow the CRC to approve protocols which involve acutely ill or potentially unstable patients.

All CRC outpatient activities are still conducted at the current CRC facility. CRC inpatients are admitted to and sleep at the Medical Department infirmary. Depending on the protocol, some inpatients spend all of the day hours at the CRC participating in protocol activities and resting in the CRC day rooms and lounges, while others are transported to the CRC for protocol activities but are then taken back to the Medical Department. Inpatients take meals at the CRC on weekdays and have meals provided at the Medical Department by the CRC kitchen on weekends. Outpatients receiving meals are served in the CRC.

In summary, the CRC presently has a dual administrative locus within MIT: As a patient-care unit, the CRC is a part of MIT's Medical Department, and all CRC committees and functions concerned with patient care and quality assurance report to the Medical Department or have been incorporated within the Medical Department's own system. However, as a research unit the CRC remains a part of MIT's Whitaker College, and all committees and functions concerned with its use for actualizing research protocols (e.g., the Advisory Committee) or providing training report to the CRC's Principal Investigator, Kenneth Smith, the MIT Vice-President who is responsible for the Whitaker College.

Core Laboratory

The change in function of the Core Laboratory from that of earlier routine screening to research analyses that support multiple protocols has now been completed. The HPLC system for amino acid analysis has been in full operation and also is now used routinely to measure physiologic amino acid profiles in plasma samples. The plasma tryptophan assay by spectrophotofluorometry has been utilized extensively by investigators and will now be routinely determined for our clinical protocols. The laboratory also routinely performs multiple radioimmunoassays for hormones. New micro methods for plasma free fatty acids, plasma triglycerides, and for glucose were set up last year and these have been utilized during the current year. Although these assays are available via the clinical laboratory, we perform them when sample sizes are limited due to blood drawing restrictions.

A major, further change in the Core Laboratory, which has proceeded very well, concerns the establishment of the capability to undertake isotope ratio (IR) and/or gas chromatograph (GC)/mass spectrometric (MS) analysis. The GCMS system was installed in March, 1987, and is routinely operating for purposes of analysis of ¹³C, ²H and ¹⁵N amino acids. Further methodological developments are underway to service the GC/MS needs of the various clinical protocols. The IR/MS is making routine determinations of ¹³C enrichment in expired air. Method development is underway to achieve the capability for routine analysis of ¹⁸O, ²H and ¹⁵N. One of the Core Laboratory technicians is now receiving training in the conduct of GC/MS determinations.

RESEARCH ACTIVITIES

During the past year, most of the research activities of the CRC have continued to be associated with three clinical areas, and to involve three groups of scientists each led by a senior professor. These areas are: Nutrition/metabolism (Professor Vernon R. Young) - an area in which the CRC constitutes the major locus of MIT's activity, and one that is a traditional component of clinical research centers; Neurochemistry/neuropsychopharmacology (Professor Richard J. Wurtman) studies on the effects of drugs, foods and hormones on brain composition and behavior, and studies on biologic rhythms in sleep and hormone secretion; and Behavioral Neuroscience (Professor Suzanne Corkin) focussing on the effects of diseases on cognitive and related brain functions and on

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genetic and other mechanism 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 are also conducting research programs involving the development of biomedical instrumentation; the analysis of human autonomic functions (e.g., the contribution of the sympathetic and parasympathetic systems in generating particular electrical frequencies detected by the electrocardiogram); visual changes resulting from neonatal effects of sex hormones on the brain; and sensorimotor disturbances. Such projects are especially germane to an institution with the resources of MIT, and the CRC directorate is committed to facilitating their development.

The uniqueness of the CRC relates to the fact that it is MIT's sole locus for carrying out investigations which require the use of medical procedures; for example, venepuncture; special diets; nutritional balance studies; hormone or drug infusions; and frequent examinations or monitoring over a prolonged period. The CRC also houses laboratories for quantifying behavioral and cognitive functions, for making on-line measurements of elective nutrient intake, and for developing new devices for measuring particular physiological parameters. Its infusion facilities are in daily use for administering deuterated metabolites, or for conducting insulin clamp studies.

Nutrition/Metabolism

During the past year the Nutrition and Metabolism group directed by Professor Vernon R. Young has continued to utilize the stable isotope tracer probes to explore dynamic aspects of nutrient metabolism in adult subjects of varying age. Major accomplishments include: (a) the development of a new tracer protocol to study the interrelationships between phenylalanine and tyrosine metabolism; (b) the development of stable isotope techniques to explore kinetics of lysine metabolism; (c) the consequences of interactions between branched-chain amino acids and the requirements for these nutrients; (d) preliminary observations on the daily energy expenditure of young adults using the doubly labeled water technique; (e) a further understanding of the ways by which the body responds to low leucine intakes and a demonstration of the concepts of nutritional adaptation and metabolic accommodation to unfavorable dietary conditions; (f) the finding that zinc and copper absorption in elderly subjects are unaffected by changes in the dietary zinc-to-copper ratio within the physiological range of intake of these trace elements.

Obesity

Dr. William Dietz and his associates have been studying body composition and energy expenditure in obese and nonobese adolescents. Basal metabolic rate (BMR) and total daily energy expenditure (TDEE) were measured in 60 free-living obese and nonobese adolescents. BMR was measured by open circuit indirect calorimetry with a ventilated hood. TDEE was measured by the doubly labeled water method. They did not find significant reductions in either BMR or TDEE among obese adolescents. These results suggest that the already obese adolescent does not have a reduced energy expenditure. In the same population, TDEE was compared to energy intake determined from dietary records. Both obese and nonobese adolescents reported energy intakes which were significantly lower than energy expenditures. Furthermore the discrepancy between intake and expenditure was significantly greater for the obese. These results suggest that the use of dietary records to determine energy requirements in adolescents will result in an underestimation of energy needs.

Dr. Dietz and his group have also been studying composition and metabolic rate in children and adolescents with cerebral palsy and myelodysplasia. The preliminary data on 10 adolescents with myelodysplasia suggests that metabolic rate is lower than normal adolescents when expressed in absolute amounts (kcal/day) but is not reduced when adjusted for FFM. These results suggest that the reduction in metabolic rate observed in this population is due to a decrease in FFM. TEE in this population is significantly less than in normal adolescents. The ratio of TEE/BMR is significantly lower in adolescents with myelodysplasia (1.35) than in normal adolescents (1.67) suggesting that a significant reduction in TEE is due to a decrease in physical activity. Paraplegics had a TEE $1.15 * BMR$ in comparison to $1.5 * BMR$ for those who could ambulate.

Preliminary data in 10 adolescents with cerebral palsy suggest that metabolic rate is reduced due to a decrease in FFM. TEE varies considerably among individuals and appears to be related to the type of cerebral palsy.

Behavioral Neuroscience

1. The Behavioral Neuroscience Laboratory under the direction of Professor Corkin and her associates with the collaboration of Dr. John H. Growdon continues to pursue a program of research seeking dissociations of cognitive, sensory, and motor functions in patients with neurological disease. Dissociations exist when one patient group performs a particular kind of task normally but is impaired in others, while another patient group shows the opposite pattern of performance. Their goal is to identify the neural substrate for different behavioral capacities. The groups that they have studied include chronic global amnesia, head injury, Alzheimer's disease (AD) and related dementias, Parkinson's disease (PD), progressive supranuclear palsy, and age-matched healthy control subjects. Some of their findings are:

a) Few investigators have studied whether the behavioral effects of brain insult in adulthood are stable after the period of maximal recovery. This issue was addressed in a 30-year longitudinal study of 84 veterans of World War II, 57 with penetrating head injury (HI) and 27 with peripheral nerve injury (PNI), matched with respect to age, premorbid intelligence, and premorbid education. Each subject was examined during the 1950s and during the 1980s; each examination included the largely verbal Army General Classification Test (AGCT) (with Vocabulary, Arithmetic, and Block Counting subscales) and the Hidden Figures Test (which measures figure-ground discrimination). HI exacerbated decline in performance time, irrespective of lesion site or cognitive test: HI and PNI subjects differed significantly in AGCT Total and Arithmetic change scores, and means were in the same direction for all other measures. In analyses contrasting subjects in each of the eight lesion groups to PNI subjects, those with left parietal-lobe injuries showed significantly greater decline from the 1950s to the 1980s on the Vocabulary and Arithmetic subscales of the AGCT, as did those with left temporal-lobe injuries on the Arithmetic subscale, whereas subjects with right parietal lobe injuries showed significantly greater decline on the Hidden Figures Test. They hypothesize that the observed reduction of cognitive capacities late in life was due to some combination of HI in young adulthood; secondary effect of the injury occurring with time; effects of stress on remaining brain tissue caused by functioning for decades in a compromised state; and changes in the brain occurring with age. Although the HI subjects were not demented, follow-up studies must assess whether exacerbated decline is a harbinger of dementia.

b) Dementia is the hallmark of Alzheimer's disease (AD), and extrapyramidal signs (EPS) are the hallmark of Parkinson's disease (PD). Many AD and PD patients display clinical and pathologic characteristics of both diseases, raising the question of whether mixed presentations reflect separate, co-occurring disease processes or the multifaceted expression of a single process. The former hypothesis predicts the EPS and dementia develop independently; the latter hypothesis predicts a correlated development. They investigated the independence of EPS and dementia in patients with probable AD; EPS scores equaled the number of signs observed (maximum = 12), and dementia scores were taken from the Memory-Information-Concentration section of the Blessed Dementia Scale. Longitudinal data (N = 64) showed that EPS and dementia significantly increased with time. Cross-sectional data (N = 137) showed that the presence of EPS was not associated with the severity of dementia; further, among patients with EPS, EPS scores were uncorrelated with dementia. The statistical independence of the progression of EPS and dementia supports the view that joint AD and PD symptomatology reflects the effects of multiple disease processes.

c) Parkinson's disease (PD) often is associated with specific cognitive deficits in the absence of dementia, including the inability to suppress inappropriate learned responses. They assessed problem solving ability in nine nondemented, never medicated subjects with PD (X age 63.8, education 14.9 years) and seven matched healthy control subjects (HCS). The 10 problems required subjects to deduce a 'poisoned food' after study of lists of three-food meals and their outcomes. Information provided by a single outcome was positive (the diner 'died') or negative ('lived'). All information (meals, outcomes, subject's deduction after each meal) was available at all times. PD subjects' performance was worse than HCS'. Most PD errors occurred on negative meals immediately following correct assessment of positive meals. Problems consisting exclusively of negative meals were performed correctly. The results suggest that subjects with PD can develop a learning set within a problem, even after a single trial, and are unable to suppress it on subsequent trials when that set leads to incorrect responses. This dysfunction must be considered when assessing problem solving and other multicomponential cognitive abilities in PD.

2. In studying the development of visual function in infants, Dr. Richard Held and his associates have found that female infants develop binocularity and vernier acuity at a significantly earlier age than male infants. This sex difference is not found in grating acuity which is limited by the properties of the receptors of the retina. Sex differences in the development of binocularity and hyperacuity suggest a hormonal influence on the rate of development of the visual cortex. Male infants show an early pulse of testosterone beginning at about one month of age. Testosterone is known to inhibit cell death and axon withdrawal in rats, and it is possible that the high levels found in male infants may inhibit cortical maturation. They have hypothesized that male infants with high testosterone levels will show a delay in the onset of mature binocular vision while infants with low testosterone levels will show an earlier onset. To date, they have found significant correlations between plasma testosterone levels at ages between five and eight weeks and the age of onset on binocularity. After that the correlations while positive are nonsignificant. In order to bolster their sample at the younger ages they propose to take blood samples at biweekly intervals from male infants beginning as early as possible. At the same intervals, tests of binocular vision will be performed. Blood levels of testosterone will be assayed and correlated with the age of onset of mature binocular vision. The results will allow them to make a finer analysis of the relation under study.

Neurochemistry-Psychopharmacology

1. In a controlled study on bulimia patients Dr. Richard Wurtman and his associates have observed that the binge-vomit cycle tends to terminate after the subject has digested and absorbed enough of the binge foods to raise the plasma tryptophan ratio (i.e., the ratio of the plasma tryptophan concentration to the summed concentrations of other circulating large neutral amino acids). These studies were designed collaboratively between MIT and investigators at the National Institutes of Mental Health.
2. Dr. Richard Wurtman and Dr. John Growdon demonstrated that oral intake of cytidyl-diphosphocholine (an intermediate in neuronal phosphatidycholine synthesis, and a widely-used drug for neurological diseases in Europe and Japan) concurrently increases plasma levels of both choline and cytidine. Parallel studies in our laboratories using neuronal cell cultures have shown that cytidine and choline potentiate each others' effects on phosphatidyl-choline biosynthesis.
3. Dr. Harris Lieberman and Dr. Amnon Brzezinski observed that preovulatory "surge" in plasma levels of LH (the luteinizing hormone) occur coincident with the late night fall in plasma melatonin levels. This observation - made in a small sample suggests that the early-night elevation in plasma melatonin physiologically supresses LH release, and that it is the fall in melatonin that releases the processes controlling LH secretion from inhibition.
4. Dr. Judith Wurtman and her associates demonstrated that while no clear changes in the circadian rhythm in plasma melatonin occur in association with the normal menstrual cycle, major changes are seen in women with secondary amenorrhea: Melatonin levels are at least twice as high, during both the day and night hours.
5. In a preliminary study on control and treated groups containing five subjects each, Dr. Donald Schomer and Dr. Judith Wurtman have demonstrated that the prolonged consumption of the phenylalanine-containing sweetener aspartame, in doses currently approved by the FDA, is associated with significant modifications in cognitive functions, specifically in the ability to accomodate to a standard learning testing paradigm. A large-scale study on this relationship is currently underway.
6. Drs. John Growdon and Benjamin Caballero have demonstrated that in otherwise-normal obese subjects, the fall in plasma large neutral amino acid levels (e.g., leucine; valine) usually observed after a carbohydrate-rich meal or snack is dampened, even though insulin secretion is normal, - and that the ability of a given dose of oral tryptophan to raise plasma tryptophan levels (and the "plasma tryptophan ratio", defined above) is also impaired. These observations imply that obesity per se would tend to diminish the amounts of tryptophan available for conversion to the brain neurotransmitter serotonin - a process known to vary with precursor concentrations.
7. In preliminary findings Dr. Judith Wurtman and her associates demonstrated that many women who attempt to stop smoking develop characteristic changes in mood and appetite, probably involving decreased release of brain serotonin and that these symptoms can be treated by a drug (d-fenfluramine) known to enhance serotonin's release. The mood symptoms include a depression which can be quantified using the Hamilton scale; the appetite symptoms include severe carbohydrate craving, leading to weight gain. These symptoms probably arise from the fact that serotonin releasing brain neurons receive a nicotinic cholinergic input.

RICHARD J. WURTMAN

Division of Toxicology

The Division of Toxicology was established as an administrative unit within the Whitaker College of Health Sciences and Technology on July 1, 1988. Research and educational programs of the Division had previously represented an area of specialization within the Department of Applied Biological Sciences, and its faculty, students and staff members held appointments in that Department until its dissolution. The Division was established within the Whitaker College in order to maintain the integrity and momentum of those programs in an optimal setting for fruitful research and teaching interactions.

FACULTY

Faculty members whose primary academic affiliations are in the Division include Professors John M. Essigmann, Steven R. Tannenbaum, William G. Thilly, Gerald N. Wogan, and Helmut Zarbl. Appointment of one additional faculty member was authorized at the time of formation of the Division, and a search is in progress for candidates for that appointment. Professors James G. Fox and Hamish Munro are also affiliated with the Division. Professors Essigmann, Tannenbaum and Wogan hold joint appointments in the Department of Chemistry.

RESEARCH PROGRAMS

The focus of the research programs of the Division encompasses the following areas: genetic, biochemical, pathological, and analytical toxicology. Major research interests of the faculty can be summarized as follows:

- Investigation of etiology of cancer in high risk populations, through the development of appropriate animal models for comparison and extrapolation to humans through measurement of covalent adducts bound to biological macromolecules. Specific projects relate to quantification of human exposures to a variety of environmental carcinogens, including aromatic amines, polycyclic aromatic hydrocarbons, aflatoxins, and alkylating agents. The importance of nitrate, nitrite and nitrosamines as environmental carcinogens, including studies of endogenous formation of N-nitroso compounds, cell mediated nitrosation and nitrosation of naturally-occurring compounds.

- Development of new animal models of human diseases, in particular as these relate to the above studies of populations at high risk of cancer. Current studies include the use of the ferret in studies of endogenous nitrosation, and the possible role of *Campylobacter* infections in the enhancement of gastric carcinogenesis.

- Molecular and cellular effects of carcinogen exposure. Current investigations focus on activation of oncogenes in chemically-induced tumors and effects of carcinogens on oncogene expression in rodents. Similar experimental approaches are being used to examine DNA from human tumors in populations at high risk as well as tumors in animals associated with known exposures to environmental carcinogens for the presence of mutations or other changes in oncogene sequences. Relationships of DNA adduct levels to cancer risk and tumor induction are being investigated in human populations at high risk as well as in experimental animals.

- Mutational spectrum analysis in relation to point mutations and chromosomal rearrangements. Methodology has been developed to detect the presence of single base mutations as well as chromosomal rearrangements at levels of sensitivity adequate to detect spontaneous changes as well as those induced by chemical mutagens. This methodology is being used to study mutational spectra in human T cells treated experimentally with mutagens of different chemical structure and mutagenic potency.

- Study of DNA adducts in relation to elucidation of their genetic effects at the molecular level. Current approaches include: determination of structural basis of mutation by radiation and chemical carcinogens; design of recombinant plasmids for mutagenesis studies; characterization of structural intermediaries produced during removal of chemical adducts from DNA; and investigations on the mechanism of action of the antitumor agent cis-platin.

- Molecular cloning and characterization of transformation *effector* and transformation *suppressor* genes. Using v-fos transformed rat fibroblasts reverted to the untransformed phenotype by treatment with chemical mutagens, attempts are being made to isolate and clone gene sequences responsible for expression or suppression of the malignant phenotype. In addition, experiments are in progress designed to identify and study the regulation of genes whose expression is altered specifically in response to transformation of cells by the Fos oncogenes.

GRADUATE DEGREE PROGRAM

During the 1988-89 academic year, a total of 25 doctoral candidates were enrolled in the degree program of the Division.

The objective of the graduate degree program in toxicology is to produce scientists professionally qualified to make original research contributions directed at improved understanding of the impacts of hazardous chemicals and other environmental agents on human health, and to educate future generations of scientists with similar interests and qualifications. Special emphasis is placed on development and application of *in vivo* and *in vitro* experimental models and approaches designed ultimately to elucidate, in cellular and molecular terms, mechanisms through which such agents induce their adverse effects. These approaches are intended to provide information useful in the identification of health hazards created by the presence of these agents in the environment. Strong emphasis is also placed on the development, validation and application of methodology for detection and characterization of adverse effects that will improve assessment of actual or potential hazards to humans resulting from environmental exposures. Utilizing biochemical, chemical and biological approaches, the training of doctoral candidates and postdoctoral trainees is concerned with: characterization of effects of toxic, carcinogenic and mutagenic chemicals at the whole animal, tissue, cellular and molecular levels; development of chemical and biological methods for the detection and quantification of these effects in humans, experimental animals, and other experimental systems; studies of metabolic activation, macromolecular binding and genetic effects; and elucidation of modes of action at cellular and molecular levels.

Although a program leading to the Master of Science degree in toxicology is offered, a large majority of students enter the program with the objective of obtaining PhD or ScD degrees. Requirements for these degrees include successful completion of (1) a major program of study fulfilling specified course requirements given below; (2) a comprehensive written and oral doctoral examination; (3) oral presentation and defense of a thesis proposal; and (4) completion and defense of a thesis based on original research that makes a significant contribution to its field. The first two to three academic terms are devoted mainly to course work. Most students, however, carry out research projects concurrently on a part-time basis during the academic year and full-time during the summer.

The doctoral qualifying examination consists of written and oral components, and is usually taken in the early part of the fourth semester of the program. Following successful completion of the written and oral examinations, students have a maximum of three semesters, excluding summers, in which to submit a proposal for the doctoral thesis research project. On the basis of the subject of the proposed work, a thesis committee is appointed, consisting of at least three faculty members, in addition to the *ex officio* thesis advisor(s). At least one member is drawn from faculty of other MIT departments, usually Biology or Chemistry, or from other institutions. For example, recent thesis committees have included members from Harvard, Brandeis, Boston University, Tufts University, Michigan State, University of Minnesota, and NIH. The adequacy of the thesis proposal as well as the general preparedness of the student for research are evaluated by the committee on the basis of an oral presentation and defense of the proposal. After successful completion of this procedure, the student embarks on full-time research on the thesis topic. Progress is monitored by presentation to the thesis committee of at least two interim progress reports prior to the final written and oral presentations and defense of the thesis. In all, completion of the doctoral requirements typically requires five years from initial enrollment into the program.

Formal requirements for the PhD program can be summarized as follows:

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Entrance Requirements

Physics I and II (MIT equivalent subjects 8.01, 8.02)
Calculus I and II (18.01, 18.02)
Organic Chemistry (Two terms)
Physical Chemistry (One term)
Genetics or Molecular Biology

Required Courses

General Biochemistry (7.05) or Advanced Biochemistry
Experimental Toxicology (Tox 210)
General Toxicology (Tox 211)
Xenobiotics: Chemistry and Metabolism (Tox 212)
Genetic Toxicology (Tox 213)
Human Pathophysiology (Tox 214)
Thesis Proposal (Tox ThP)
Thesis (Tox ThG; minimum 24 units)

Other Elective Courses

Chemicals in the Environment (Tox 104)
Principles of Toxicology (Tox 105J)
Laboratory Animals in Biological Experimentation (Tox 218)
Research Problems (Tox 301/302)
Teaching Experience (Tox 304)

In addition to the above requirements, participation in a weekly seminar program is mandatory for all students (predoctoral and postdoctoral). Each trainee is required to make at least one oral presentation per year at a weekly seminar attended by all members of the toxicology program, including faculty, research staff, students and postdoctoral associates. Experience in formal oral presentations gained through this program has greatly improved performance in doctoral examinations, thesis defenses, presentations at scientific meetings and similar events for all trainees in the program.

HONORS AND AWARDS

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

Dr. Helmut Zarbl is Robert A. Swanson Assistant Professor of Life Sciences.

The M. M. Znaty Award for Graduate Research was presented to Ms. Marcela Chackal-Roy in recognition of her doctoral thesis research with Professor Robert S. Langer.

The Bernard S. Proctor Undergraduate Research Award went to Mr. Andrew Norris, on the basis of his SB thesis research project.

Ms. Cindy Wang, an MS candidate in the research group of Professor W. G. Thilly held the Ida M. Green fellowship for the 1988-89 academic year.

Mr. Brian Donahue, a doctoral candidate with Professor John M. Essigmann, will hold a Surdna Foundation predoctoral fellowship during the 1989-90 academic year.

GERALD N. WOGAN

Associate Provost for Educational Programs and Policy

Office of the Dean for Undergraduate Education (Committee on the Undergraduate Program, Undergraduate Education Office, Concourse, ROTC Programs)

INTRODUCTION

In the four years since the appointment of MIT's first Dean for Undergraduate Education, the overall office has focussed on four objectives:

- o Establishing as an Institute-wide priority the quality of the undergraduate academic program;
- o Forging from several separate activities an integrated and effective office to give strong and often times new support to departmental and faculty curricular and teaching enterprises;
- o Providing leadership to an Institute-wide review of the current undergraduate academic program and the broader undergraduate experience overall; and
- o Achieving a viable and strong faculty Committee on the Undergraduate Program (CUP).

Progress toward these objectives is steady and encouraging. But, the road is long and there is a long way yet to go. The Dean is coordinating an approach to the large arena of issues surrounding classroom space allocation, renovation, and new construction. Recommendations to the Provost for appointments of faculty to teaching chairs are being coordinated to reinforce Institute educational goals. CUP maintains momentum and its trajectory at just this moment when the toughest issues will be broached: ones concerning the balance between general education and departmental degree requirements. At the same time, the Institute initiative to launch a "contexts" experience must emerge from differing local visions to an Institute-wide perspective and commitment.

The mission of the Dean is simply stated:

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

There are two fundamental issues underlying this mission. The first pertains to the content, form, and character of the undergraduate academic program. The faculty seeks to regain broadly-based agreement about the purpose of the undergraduate academic program and its intended audience. The second issue is that of achieving a proper balance of faculty

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commitments between research enterprises, including postdoctoral education and graduate education, on the one hand, and undergraduate education, including non-classroom encounters, on the other. Both of these issues will require as much as a decade or more to address and are not amenable simply to curricular decisions or to academic legislation: these treat the symptoms, not the source. The nub of things is MIT's own culture. It is here that the Institute's strengths and uniqueness lie. And it is here that the viscosity surrounding change may be high. It is encouraging that Institute-wide consciousness concerning such fundamental educational issues is widespread and that an eagerness to address them is manifest. The next few months will provide opportunity to test the Institute's will to change.

MARGARET L.A. MACVICAR

COMMITTEE ON THE UNDERGRADUATE PROGRAM

For academic year 1988-89, the Committee on the Undergraduate Program viewed its task to be to bring issues and threads together and focus on the process of communicating CUP's agenda to others. This was stated at CUP's first meeting in September and became the theme for the year. The Committee's work focused on preparing proposals for Faculty votes on the first year and the science requirements, hearing from various Institute groups, and continuing work begun the previous year.

CUP received the report from the Committee on the First-Year Program and immediately began to formulate proposals to the Faculty requesting endorsement for the principle of increased flexibility of when undergraduates can take General Institute Requirement subjects and changing grading policies for undergraduates, particularly during the first year. Motions presented at Faculty Meetings generated much discussion, followed quickly by alternative motions for grading. Members of the Faculty defeated the proposal for flexibility. Throughout April and May, CUP brought together dissenting groups in an attempt to unify the proposals. In May, the Faculty accepted an alternative motion that designated Pass as C or better, limited the number of credits freshmen can take, and changed junior-senior Pass/Fail to Pass/No Record. CUP will review these policies in Spring 1994, and report to the Faculty at that time.

The Committee heard frequently from the co-chair of the Science-Engineering Working Group, Professor David Wormley, a member of CUP. The Working Group made several recommendations regarding the Science Requirements, which CUP then incorporated into a motion for the Faculty to endorse inclusion of biology in the Science Core, revision of the Science Distribution Requirement, and formation of a Committee on the Science Component of the General Institute Requirements. The Faculty accepted the motion, and a two-semester subject incorporating biology, chemistry, and materials science was given a three-year trial period by the Committee on Curricula.

Other topics that came before the Committee included the following:

- o CUP endorsed a request from the School of Humanities and Social Science for degree designations for humanities majors. This proposal was considered consistent with the general goal of the current undergraduate program review to strengthen the role and presence of humanities at MIT and viewed as an appropriate way to recognize the autonomy and intellectual strength of the divisions within humanities. It also balanced the minor designation voted previously by the Faculty.
- o Professor Keith Stolzenbach, chair of the Committee on Undergraduate Admissions and Financial Aid, was a guest of CUP for the year. He reported frequently on CUAFA's review

of MIT's admissions policies prior to his final report to the Faculty in May. Professor Francis Low, chair of the Committee on the Contexts Experiment, solicited opinions and advice from CUP members as his committee began its work, as did Professor Molly Potter, chair of the Freshman Housing Committee.

- The subcommittee working on Educational Commons Activities devised a planning process for deans and departments heads for encouraging faculty participation in a variety of activities. Guidelines for the process were then distributed.
- Dr. David Wiley, also a CUP guest for the year, brought calendar issues to the Committee, in particular, compression at the end of the spring term. He proposed alternatives which were considered by CUP members and which will be considered further next year.

CUP hosted Provost John Deutch who offered his perspective on the CUAFA review, housing, the budget deficit, Project Athena evaluation, Contexts subjects, the advising system, and IAP.

CUP members made two field trips during the year. The first was to Project Athena, where faculty members made effective presentations about the integration of Athena into their classwork. The second was to the Experimental Study Group, undertaken because of CUP's special interest in the experiences of the freshman year and the special bonding that takes place at the three alternative programs. The visit provided a wonderful opportunity for the Committee to leave the meeting table and observe first-hand the special qualities of ESG.

CUP bid farewell to departing members Messrs. Yonald Chery and Alan Davidson (both undergraduate representatives), Dean Jack Kerrebrock, and Professors Thomas Greytak and Donald Schon.

LAURA B. MERSKY
Secretary to CUP

THE UNDERGRADUATE EDUCATION OFFICE

Drawn together as a synthesis of the offices of the Writing Requirement, the Undergraduate Research Opportunities Program (UROP), and Curriculum Support, the Undergraduate Education Office will enter its third academic year as the programmatic arm of the Office of the Dean for Undergraduate Education. Prof. Benson Snyder, tenured in the Office of the Provost, is associated with the Undergraduate Education Office in the area of educational studies.

The academic year was one of intense activity and growing definition of the Office's role in aiding undergraduate academic and reform efforts by bringing people together, supporting faculty committees, and nourishing embryonic programs and ideas. The Writing Requirement advanced to a new stage with departments taking increased responsibility for the writing of their majors. UROP spun off a mini-program for IAP, secured funding for undergraduate biology research, and firmed connections with national undergraduate research groups. Curricular efforts continued toward improving teaching and encouraging new educational endeavors. Specific educational studies were undertaken in several areas responding to Institute needs. Two undergraduate seminars were offered by UEO staff.

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Educational Studies: Interview Project of the Class of 1991

This was the third year of Interview Project activities and the second year of interviews with students in the Class of 1991. Of the original 50 randomly-selected students (five per cent of last year's freshman class), 46 students were interviewed at least once during their first year. This group was representative of the class in terms of gender, ethnic status, and living group. The original goal of the project was to obtain an ongoing, reliable, and current picture of the class as students proceeded through their years at MIT. Additional goals include surveying attitudes and opinions about classes, instructors, academic advice, and so on.

In the summer of 1988 the coding of the three rounds of student interviews with last year's freshman class was completed. During the fall term an analysis of these interviews was begun by Professor Benson Snyder. Since all interview data was coded by topic area (program, subject number, etc.), some verbatim transcript material containing all remarks made by students about a certain program, subject, and/or topic has been provided to a number of committee chairs.

In the spring term, work was begun on the fourth round of interviews with the students in the Class of 1991; the Sophomore Interview Project was again fortunate to have the assistance of seventeen staff volunteers from all of the freshman-related support offices--UEO, UASO, OME, the undergraduate offices in humanities, chemistry, math and physics, admissions, Concourse, ESG and ISP--to hold interviews with as many of the 46 original students as possible. This second year of interviews is characterized by a more refined coding protocol and well-documented process which will make possible an institutionally-useful analysis of various aspects of students' MIT experience.

The Undergraduate Research Opportunities Program (UROP): Approaching Twenty

With a twentieth anniversary approaching, UROP is the oldest of the many programs of undergraduate research that now exist nationwide. UROP continues to influence and sustain connections with other institutions concerned with building and strengthening their own programs. It is represented by assistant dean for undergraduate research Jane Sherwin on the board of the National Conferences on Undergraduate Research which held its third conference in San Antonio, Texas, this spring.

Past funding sources continue to help support the program: grants from The New England, TRW, Sea Grant among others. A major new source of funding in the life sciences has come from the Hughes Institute which has granted \$1 million for undergraduate research in biology over the next five years. In May 1989 the first Alumni Fund mailing on the subject of support to the newly created UROP Endowment Fund was completed.

The UROP student stipend was increased with an increase in Institute funds beginning with the summer of 1989, resulting in an hourly wage increase from \$5.50 an hour to \$6.25 to match a concurrent increase in the Institute minimum wage. This was the first stipend increase since the 1985-1986 academic year. Both participation and faculty support for UROPers decreased slightly, from the all-time high levels of 1987-88 to the 1986-87 levels. Such fluctuations are familiar and do not appear to represent a trend.

Undergraduate Research Initiatives

Student Research Partners, run only as a pilot program last year to give additional encouragement to first year students interested in research, was expanded in IAP 1989 to include some 13 freshmen who were matched up with more experienced UROP "mentors" for a month of exploration. Demand was high and additional growth is expected next year.

Ways of encouraging undergraduate ingenuity and initiative in design are being sought. The assistant dean for undergraduate research, with the financial assistance of Jordan Baruch, '47, is working with the Technology Licensing Office, Professors J. Meldman and Robert Rines, head of the Franklin Pierce Law Center, to develop a program for patenting undergraduate inventions.

Other efforts include cooperation with Sea Grant and Ocean Engineering to encourage undergraduate participation in marine research. Joint funding of student stipends in the summer of 1989 on a hydrodynamics project will be followed by submission of a proposal to the NSF for additional funding next summer.

Coordination and Support of Collaborative Activities Between Mathematics and Physics

The Departments of Mathematics and Physics, with assistance from UEO, encouraged coordination between lecturers and recitation section instructors in core subjects taught during the fall and spring terms. Students enrolled in 8.01 during the fall term and in 8.02 during the spring were assigned to one of three types of recitation sections based on their mathematics enrollment (what has come to be called "tying"). This refinement in the scheduling process is popular with physics recitation instructors, as it enables them to work with a group of students whose mathematics background is more uniform. In addition, a number of paired recitation sections in mathematics and physics each contained a common group of students ("linked" sections). After a number of years of experience with linking, it is clear that this arrangement is more popular and workable during the fall term core math and physics subjects than during the spring. Meetings were held throughout the term with various participants in the collaboration--the linked recitation instructors, the lecturers, academic officers, departmental administrators, and included as well staff of the Admissions Office. These meetings focussed on the curriculum and performance and abilities of the freshmen in this year's class.

UEO worked with individual recitation instructors; many instructors took advantage of the opportunity to have someone sit in on lectures and provide a critique of teaching style and effectiveness.

UEO also assisted with the mounting of a pilot version of Physics II--8.02X--that included pre-term coordination of publicity, mailings to the 300 students who indicated interest in the subject, oversight of the student selection process, and assistance on Registration Day. We are grateful to the efforts of the Registrar's Office, particularly those of Ms. Mary Jasinski, on behalf of both the linking and tying experiments in addition to their work to support the new 8.02X subject.

General Support to Classroom Teaching

As a spin-off from UEO support of the collaboration between mathematics and physics, program administrator Maureen Horgan has become involved in activities to support classroom teaching. An IAP seminar "Teaching at MIT: The Torch or the Firehose?" was held during January as a follow-up to the fall term orientation programs for new faculty and teaching assistants. It was jointly sponsored by the UEO and the Dean of the Graduate School. Plans for fall orientation are currently underway. UEO is also working with the mathematics and physics departments to develop orientation for instructors who will be teaching in the freshman math and physics core subjects. In addition, the UEO is planning to assist the School of Humanities and Social Science in conducting an orientation session for new faculty.

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Ms. Horgan assisted Professor Edward Crawley, chair of the School of Engineering Faculty Instructional Resources Program (FIRP) in obtaining information about all academic departments' procedures, including forms used, for evaluating teaching. To assist this and other efforts, UEO is assembling a small library of articles and pamphlets devoted to topics about teaching, and plans to produce a reference guide to existing MIT programs relating to faculty development.

In the spirit of serving as a science core coordination office, we once again collected and distributed information about the core science subjects, and continue to work with Graphic Arts to streamline the distribution of student pictures to both freshman instructors and upperclass departments. Hiring students to erase blackboards for freshman core science lectures given in the larger lecture halls has also continued and has, in fact, received funding assistance from Physical Plant this year.

Coordination and Support of the Contexts Experiment

UEO assisted the CUP-sanctioned experiment on the "Human Contexts of Science and Technology" for the second year, providing support and the essential "switching function" needed to coordinate the Context Subjects program, acting as "Context Headquarters." Activity included regular contact with and moral support to the faculty teaching the twelve Context subjects, coordinating scheduling and catalogue activity in association with participating departments, publishing brochures and overseeing general term-time publicity for all Context subjects. UEO also managed the Context subject on AIDS, supported the Interschool Working Groups and the work of the current Context Review Group. A number of Context "experiments" that required our imagination and assistance were undertaken by the review group. Of note were the two Context Workshops offered to the MIT community during the spring term, one on the greenhouse effect and the other designed to provide a forum for faculty-student discussion of animal rights issues. A report of the Context Review Group is currently being prepared.

Meetings of Undergraduate Academic Officers

Assistant dean Margaret Richardson instituted regular meetings of all departmental undergraduate academic officers. Three took place this past year, providing a chance for faculty department representatives to hear from committee chairs about ongoing educational reviews (e.g., CUAFA, Contexts, the Science-Engineering Working Group) and for committee chairs to solicit information and opinion from departments before completing their deliberations. These gatherings have effectively established the existence of an informal "undergraduate education faculty council."

Visits to New Faculty

In the spirit of meeting the educational needs of both students and faculty, UEO staff met informally with new members of the faculty. During the late winter and early spring virtually all 60 new faculty were visited by a staff member from the UEO to talk about MIT resources, policies, procedures, and anything else the new faculty wanted to discuss. These visits were productive as they provided insights into the way new members of the community react to MIT, and UEO an opportunity to assist and advise where appropriate. This effort will be repeated next year.

Tech Coop Liaison

Specific faculty complaints about textbook service led the UEO to establish a liaison between faculty and the Tech Coop. Assistant dean Leslie Perelman, with help from the Coop, negotiated a formal procedure for placing textbook orders with the result that the Coop subsequently distributed "A Guide to Faculty Textbook Ordering." A textbook contact person in each academic department was identified and a Tech Coop-departmental meeting was sponsored. Evidence of the improvement in relations that has come about is evident in the Coop's report of 669 textbook orders received for the 1989 fall term compared with 160 received by the same date last year, and, on the MIT side, a noticeable improvement in service to faculty.

Other hopeful signs of improved relations exist: the Coop is in the process of expanding and making more prominent a section of books by MIT faculty; with the advice of several faculty, the UEO is helping the Coop develop a list of books for an expanded reference and general academic book section.

Liaison With the Libraries

Working with Associate Dean of the School of Humanities and Social Science Philip Khoury and the staff of MIT Libraries, the UEO has actively begun pairing HASS-D course instructors with appropriate reference librarians in order to make library materials more accessible to students enrolled in HASS-D courses.

Additional Curriculum-Related Activities

UEO provided the administrative support to the Science-Engineering Working Group throughout its deliberations about the freshman year program.

Several UROP projects were conducted that supported curriculum development: A team of students prepared experiment kits for freshman chemistry, other students developed curricular software for several departments, and others prepared a video library on third world countries for Political Science.

UEO continues to provide and distribute documents of interest and use to departments and academic administrative officers, including the "Resource Guide for Academic Officers," a short list of key academic personnel in departments, end of term grade statistics in the freshman core subjects, and so on.

Once again UEO assisted associate provost Jay Keyser with his unofficial sampling of student opinion survey via a letter sent to all seniors at the end of the spring term. Forty-seven responses were received to the approximately one thousand letters sent. Although student responses are too few to be considered a representative sampling, the thoughts and opinions of those who do write are often compelling, sometimes disturbing, and always useful in stimulating discussion about the undergraduate experience. And, students appreciate the chance to be heard.

Together with the MIT Department of Physics and a physics faculty member at University of Massachusetts at Boston, UEO sponsored a meeting with high school physics teachers. In early May, Professor A. French chaired a meeting with fifteen local high school physics teachers to talk about content in physics subjects at the secondary level, to gather opinion about the new 8.01X-8.02X physics sequence being designed at MIT, and to begin what may be an ongoing dialogue between people at MIT and physics teachers at the high school level. Another meeting convened by Ms. Sherwin and Ms. Richardson brought together faculty who share an interest in primary and secondary education.

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The Writing Requirement and the Academic Departments

Transfer of the administration of Phase Two of the Writing Requirement to the various academic departments occurred with a minimum of difficulty. No student was prevented from graduating by failing to satisfy the Requirement this academic year. Much of this success can be attributed to the efforts of departmental writing coordinators and the staff of the writing cooperatives in the Writing Program.

A workshop for writing coordinators is planned before the beginning of the 1989 fall term and the Writing Requirement Coordinator will continue working with individual coordinators to develop additional ways instruction in writing can be integrated into specific courses.

The Class of 1989 as a whole completed the Writing Requirement earlier than the two previous classes, demonstrating that the Requirement is proceeding to become an integral part of the undergraduate curriculum. In 1987, the first year students were graduating under the Writing Requirement, 39% of seniors did not complete Phase Two until their second term senior year. This academic year witnessed the first significant decrease (to 30%) in last-semester completion rate. While this rate is still far from the goal of having all students complete the Requirement by the end of junior year, the growing number of writing cooperative subjects and the new deadline for completion of Phase Two approved by the faculty in April 1988 (Registration Day of the semester in which they are to graduate) appear to be accelerating the completion process.

This year all laboratory subjects in Electrical Engineering and Computer Science became writing cooperatives, and new writing cooperatives were established in Physics and Economics. The percentage of students satisfying Phase Two through writing cooperative subjects has increased from 53% for the Class of 1987 to 69% for the Class of 1989. The percentage of students fulfilling Phase Two by taking a writing subject has remained fairly stable (7% in 1987 and 9% in 1989).

The Writing Requirement and Phase One

In the UEO, the Writing Requirement Coordinator administers Phase One of the Requirement and the freshman essay evaluation.

Students are now asked to write two essays for the essay evaluation, the first on a primarily narrative or descriptive topic, the second on a primarily argumentative topic. In an attempt to tie in the evaluation with an orientation event, students were given an ethical dilemma as their second essay topic and invited to participate in a colloquium held later that week where the same topic was discussed.

As a result of the vote of the faculty vote in April 1988, students are now required to complete Phase One by the middle of the first semester of their sophomore year or lose the option of submitting a paper to fulfill the Requirement.

Committee Membership

Special efforts were made this year to assist the Committee on Undergraduate Admissions and Financial Aid (CUAFA) on which Dean MacVicar is represented by UEO Director Norma McGavern. A lengthy and full study of undergraduate admissions was undertaken by the committee this year with administrative support provided by the UEO. Its final report was presented to the faculty on May 17, 1989. The CAP, with Ms. McGavern representing Dean MacVicar, came to agreement regarding evening exams and is preparing faculty guidelines on this issue.

Ms. Richardson represents the Dean for Undergraduate Education on the Committee on Curricula (COC). Ms. Richardson also represents the Dean on the ad hoc committee appointed to review the relationship between MIT and ROTC programs, and provided administrative support to the Science and Engineering Working Group.

Coordinator of the Writing Requirement Perelman provides administrative support to the Committee on the Writing Requirement, the source of oversight for the Writing Requirement.

Undergraduate Seminars

Ms. McGavern offered the undergraduate seminar "Making Oral Presentations" in the fall and spring semesters. Dr. Perelman gave a freshman advisor seminar in the fall term entitled "Politics and the English Language in 1988."

Affirmative Action: Personnel

UEO is a small office, having five administrative staff and two and one-half support staff members. A support staff position opened up this year for which there were seven finalists from eleven interviews; no underrepresented minority candidates presented themselves for interviews.

Affirmative Action: Undergraduates

Underrepresented minority in UROP as a percentage of total UROP participants has increased steadily for the past three years, from 2 percent in 1986-87 to 7 percent in 1988-89. The participation rate does remain lower than that for underrepresented minorities as a percent of total undergraduate enrollment. The percentage of women UROPers continues at about the level of their undergraduate enrollment.

In one joint effort initiated by UEO, the assistant dean for undergraduate research and the director of the Office for Minority Education (OME) conceived a summer program in physics for minority students, a portion of whom would be invited from non-MIT undergraduate programs. While this particular plan was not funded by NSF as requested, it is hoped that other plans increasing minority participation will gain ground nevertheless. UROP and OME are currently engaged with the Dow Chemical Company in establishing a new Dow UROP Fellows Program. Minority students will be invited to apply through UROP for term or summer fellowships funded by Dow for work with faculty in the departments of Chemistry, Chemical Engineering, and Materials Science and Engineering. Fellows will have the opportunity to meet with representatives from the company and present their research results.

A study was conducted of the performance of underrepresented minority students on the Freshman Essay Evaluation in relation to their SAT Verbal scores. Those students with SAT Verbal scores of 550 or below performed at the same level as non-underrepresented minority students with comparable scores. However, underrepresented minority students with SAT Verbal scores of 600 and above had a significantly higher pass rate than equivalent non-underrepresented minority students.

Personnel

Staff reporting to the Dean for Undergraduate Education include Ms. Norma McGavern, appointed UEO Director in January, Assistant Deans Leslie Perelman, Margaret Richardson and Jane Sherwin, Program Administrator Maureen Horgan, and Professor Robert Rose, Director of Concourse, and Ms. Cheryl Butters, Concourse Program Administrator, and Professor Benson Snyder, tenured in the Office of the Provost.

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In July 1988 we welcomed Ms. Robin Pachtman as a full time Senior Staff Assistant, and Ms. Stacia Conklin as half-time Senior Staff Assistant. Ms. Pachtman's primary responsibilities lie with Curriculum Support and UROP, while Ms. Conklin primarily aids the Writing Requirement. In December 1988 Administrative Assistant Dianne Brooks left UEO to become Administrative Officer for the History section of the School of Humanities and Social Science.

Dr. Gregory Jackson joined the Office of the Dean for Undergraduate Education as Special Assistant for Educational Studies in May to work for the coming year with the committee studying MIT computation needs in the 1990's and beyond, and will also provide guidance for educational studies efforts in the Undergraduate Education Office. We were fortunate in January to be able to appoint a new Administrative Assistant and office manager, Ms. Cynthia Rose. In addition to serving as general factotum, Ms. Rose will spend one-quarter time in the coming year assisting Dr. Jackson and the Computation Committee.

We are indebted to temporary staff assistant Jonathan Larsen, to Marsha Kaufman who preceded Jonathan, to our extremely capable long-time computer consultant Jae Sang '89, and to the many student office assistants who have so ably helped the UEO this year: Michelle Bierbaum '92, James Dailey '90, Teresa Lyons '90, Wendy Park '91, Angeli Salgado '89, Ken Schneider '92, Sheryl Shanks '89, Corinne Wayshak '89, and Deborah Wells '92, and our main Interview Project transcriber Kerry Skiffington.. Thanks are also in order to the members of Alpha Phi Omega who proctored the Freshman Essay Evaluation.

NORMA G. MCGAVERN

STACIA CONKLIN
MAUREEN A. HORGAN
ROBIN PACHTMAN
LESLIE PERELMAN

MARGARET S. RICHARDSON
CYNTHIA ROSE
JANE SHERWIN
BENSON SNYDER

CONCOURSE

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

Statistics

Sixty-five students enrolled in Concourse for the fall term. Of these, 37 were male, 28 female, 57% and 43% of the total respectively.

Nineteen of these students (10 male, 9 female) were minority students, 29% of the total enrollment.

The spring semester had a total of 57 students, 33 male and 24 female, including in the total 21 minority students (37%).

With regard to academic performance, it is notable that the Concourse Class of 1991 performed, in its sophomore year, as well as the Class of 1991 on the whole, although the scholastic indices for the Concourse Class of 1991 as entering freshmen were significantly below the mean for the Class of 1991 on the whole. We tabulate these data below:

**COMPARISONS OF ADMISSIONS STATISTICS AND ACADEMIC PERFORMANCE DURING
SOPHOMORE YEAR FOR CONCOURSE CLASS OF 1990**

GROUP	Number of students	Average scholastic index fall term	Median grade pt. average spring term	Median grade pt. average
Students enrolled in Concourse for full year	47	54	4.0	4.2
Class of 1991 overall	829	61	4.1	4.2

Last year's Concourse students (1987-1988; MIT Class of 1991) entered the following disciplines:

26 students (68%) entered departments within the School of Engineering;
 8 students (12%) entered departments within the School of Science;
 1 student (3%) entered a department within the School of Architecture and Planning;
 1 student (3%) entered a department within the School of Humanities and Social Science;
 2 students (5%) remained undesignated.

Of the engineering majors, the most popular department was Electrical Engineering and Computer Science (9 students) followed by Mechanical Engineering (7), Aeronautics and Astronautics (5), and Chemical Engineering (3). In the School of Science, there were 4 Biology majors and 2 Physics majors. The remainder were spread out evenly, with one or two students per department.

Faculty and Staff

The extensive role played by undergraduates in Concourse makes extraordinary demands on the talent, energy and collegiality of the senior faculty, the core of the community. The five senior faculty have well over a century of teaching experience between them, and have all been recognized for teaching excellence and commitment by awards or prizes at some time in their careers. At this time they have been together in Concourse for periods ranging between 4 and 8 years, and the continuity has greatly helped communication and coordination. Members of the Concourse Faculty for 1988-89 were: Professor Robert M. Rose, Department of Materials Science and Engineering; Professor Kenneth R. Manning, Director, MIT Writing Program; Professor Emeritus Irving Kaplan, Department of Nuclear Engineering; Dr. Mangol Bayat, Dr. Thomas Philipp and William Haas, MIT Writing Program; Dr. Ross L. Finney and David Yavin, Department of Mathematics; Dr. Edwin Taylor, Department of Physics and Massimo Russo, Department of Mechanical Engineering.

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

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

Academic Developments

SP3H2, "Islam and Modernity," a twelve unit Humanities Distribution course, which was developed and newly presented in the 1987-88 year during the spring term by Dr. Mangol Bayat and Dr. Thomas Philipp, was continued this year. This course begins with an introduction to Islamic religion, culture and institutions and the response of Islam to the rise of the West and Western ideas; it ended with an analysis of the conflicts which have arisen between secular nationalist aspirations and fundamentalist Islamic ideals. Conceived as an experiment, the course complements the preceding fall term presentation, which dealt with the scientific revolution in the West, perfectly. As the first year was quite successful, we repeated the course in the 1988-9 year.

The Concourse Elective is designed to connect the core presentations with each other and with human experience in innovative and provocative ways. The theme of the 1988-9 elective was "Models and Reality." An important goal of the course was to convey the ideas and development of theories and models; in recent years all the Concourse faculty have observed that incoming students are increasingly uncomfortable with abstractions, and that this constituted a real impediment to education in all fields. Consequently the elective discussed subjects such as: free fall; Dr. Frankenstein's problem; ancient Greek models; Copernicus and Galileo; evolution; relativity; epidemics; economic models; animal rights; crystal structures; black holes; abortion; drugs, recreational and therapeutic; "smart" materials; learning and education; and musical sound. Each of these seemingly disparate subjects has at its core the necessity of construction of artificial models of limited applicability.

The core presentations continue the successes of previous years. In the first term physics and calculus are coordinated, with some instruction in common, for instance in graphing and roots and the solution of first-order differential equations. Two areas of traditional conceptual difficulty, scalar and vector fields and normal modes of oscillation are emphasized. The physical problems from which calculus developed are presented. The objective is to provide the analytical tools to facilitate 18.03 Differential Equations and 8.02 Physics II. Experimental 8.02X "take-home" kits developed by Prof. John King were tried out by 20 volunteers, who reported considerable enrichment of their understanding of electromagnetic phenomena. First term Humanities concentrates on the history of ideas in science, from ancient Greece to the Age of Enlightenment, and the relationship between mathematical abstraction and natural observation. Concourse chemistry, essentially a synthesis of 3.091 Introduction to Solid State Chemistry and 5.11 Principles of Chemical Science, contains the essence of each but is identical to neither. Again, the coverage is paced to connect with, reinforce and illuminate the other core presentations and to encourage further exploration. This presentation serves as a prerequisite for 5.12 Organic Chemistry or for any course having 3.091 as a prerequisite.

As in past years, the personal and professional growth of the undergraduate teaching assistants has been impressive, and Concourse alumni and alumnae have gone on to serve with distinction in the wider communities. We congratulate Parag Patil, a former Concourse student and an enthusiastic teacher/tutor in Concourse for three years, on the award to him of a Marshall Scholarship.

CHERYL BUTTERS
ROBERT M. ROSE

RESERVE OFFICERS TRAINING CORPS (R.O.T.C.)Air Force ROTC

The Air Force Reserve Officer Training Corps (AFROTC) program at MIT continues to provide challenging and comprehensive leadership and academic training for students attending MIT, Harvard, Tufts, and Wellesley. Year-end enrollment in AFROTC as of June 1989 was as follows:

	<u>FRESHMEN</u>	<u>SOPHOMORES</u>	<u>JUNIORS</u>	<u>SENIORS</u>	<u>TOTAL</u>
MIT	25	17	29	26	97
Harvard	5	3	2	5	15
Tufts	5	7	1	4	17
Wellesley	<u>1</u>	<u>0</u>	<u>1</u>	<u>0</u>	<u>2</u>
Total	36	27	33	35	131

Besides providing opportunities for the development of leadership skills, the AFROTC program provided MIT cadets with over \$1.3 million for tuition. Cadets from the other schools received tuition payments exceeding \$.41 million. Additional payments for textbooks and subsistence exceeded \$.15 million.

As in the past, several special cadet activities highlighted this year's training for AFROTC students. The Arnold Air society (AAS) Squadron, a professional honorary service, participated in local and national conventions, performed community service and awareness functions/events, and participated in fundraising efforts for local charities. During the local convention our AAS squadron campaigned for and was elected the area headquarters for the 89/90 school year responsible for coordinating and administering all AAS activities for Northeast area units. The Blue Eagles cadet drill team and the cadet color guard represented AFROTC in local parades and ceremonies. Other events included the annual Tri-Service Awards Banquet, the Military Ball, and the annual Tri-Service Pass-In-Review. The Air Training Command Inspector General inspected the unit in May and rated cadet training excellent. The year concluded with the traditional commissioning at the USS constitution.

Thirty-three senior cadets received commissions as second lieutenants in the Air Force. Six of these will go on to pilot training and one will go to navigator training. In addition, twelve of these lieutenants were offered the opportunity to pursue advanced degrees before entering active duty and one will spend a year as an intern in the office of the Governor of Illinois.

Colonel Gary G. Nelson, AFROTC Detachment Commander and Captain Brian K. Mazerski completed their second year of dedicated service at MIT. Additionally, Captain Ray Levias and Captain Charles D. Barondes completed their first year at MIT. Captain Naida D. Larson will depart at the end of July.

COLONEL GARY G. NELSON

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Army ROTC

The 1988-89 Academic Year was another productive one for the Army Reserve Officers' Training Corps (ROTC) program. Overall enrollment was the highest in the past five years. Over the academic year, a total of 102 students participated in our program, and at year's end, 95 of those students were still enrolled.

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

	<u>FRESHMEN</u>	<u>SOPHOMORES</u>	<u>JUNIORS</u>	<u>SENIORS</u>	<u>TOTAL</u>
MIT	14	14	12	13	53
Harvard	6	5	7	2	20
Tufts	4	9	1	2	16
Wellesley	<u>1</u>	<u>1</u>	<u>3</u>	<u>1</u>	<u>6</u>
Total	25	29	23	18	95

Of the 53 MIT students enrolled, 40 are currently recipients of Army ROTC scholarships and five others have applied. These scholarships pay tuition, a monthly allowance of \$100, and a once-a-year textbook allowance of \$370. The value of these scholarships to MIT for school year 1988-89 was \$540,000. We anticipate that for school year 1989-90, approximately 40 MIT cadets will be on scholarship with a value to MIT of approximately \$560,000.

This year the Army ROTC Department commissioned 14 new second lieutenants, 10 of whom were from MIT. Of the 14, four are entering graduate school, five will be reporting immediately to active duty, and five are serving in the Army Reserve. We fell short of our commissioning mission from our higher headquarters of 18, but expect to meet it for school year 1989-90.

During the year, Army ROTC again sponsored the Annual Tri-Service Awards Banquet with over 100 cadets receiving awards from 45 different organizations. Representatives of the MIT, Harvard, Tufts and Wellesley administrations attended the banquet. Professor Alvin W. Drake was the guest speaker. Army ROTC also participated in various Tri-Service events sponsored by the other services such as the Military Ball, athletic competitions, the Annual Tri-Service Pass-In Review and Parade, and the Tri-Service Commissioning Ceremony at the USS Constitution, with President Paul Gray participating.

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

The ROTC Faculty Committee, under the chairmanship of Professor Alvin W. Drake, continued to provide timely advice and support of the ROTC programs. Members of the committee, along with other members of the faculty and Lincoln Labs, participated in over 25 scholarship boards throughout the year. The professional evaluation of scholarship potential rendered by members of the MIT community will be of great value to each applicant and to the Army.

LIEUTENANT COLONEL EDWARD D. HAMMOND

Navy ROTC

The 1988-89 academic year was successful and productive for the Navy Reserve Officer Training Corps (ROTC) Program. Total enrollment of 177 reflects a level non-scholarship participation and 18 (7 MIT, 7 Tufts, 4 Harvard) fewer freshmen scholarship participants. Offsetting the lower number entering the program is increased retention in good standing of those in the program. This is attributed to the performance of each midshipman and to the positive impact of the program. A breakdown of enrollment by year and institution follows:

	<u>FRESHMEN</u>	<u>SOPHOMORES</u>	<u>JUNIORS</u>	<u>SENIORS</u>	<u>TOTAL</u>
MIT	28	20	20	28	96
Harvard	16	12	11	6	45
Tufts	4	8	11	2	25
Wellesley	<u>1</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>1</u>
Total	49	40	42	36	177

Of the 49 freshmen, 11 are in the non-scholarship College Program. All but one of the sophomores are in the regular Scholarship Program.

The Navy ROTC again sponsored the Tri-Service Commissioning Ceremony aboard the USS Constitution. President Gray, Professor Drake and other MIT representatives joined Rear Admiral Firebaugh, guest speaker and commissioning officer. The Navy ROTC Department commissioned 29 men and 5 women as officers in the United States Navy and Marine Corps. 13 were selected as Surface Warfare Officers, 4 as Submariners, 2 as Pilots, and 2 as Civil Engineers, and 1 each for Naval Reactors Staff, Cryptology and Supply. Not included is a Submariner to be commissioned prior to October 1989, and 3 who will earn masters degrees or additional majors before commissioning. Action by the MIT ROTC resulted in the first-ever ROTC midshipman commissioned and sent directly to medical school. This follows last year's first Course XV graduate who was assigned to the Medical Service Corps, also resulting from MIT ROTC action.

Navy ROTC also sponsored the annual Tri-Service Pass-In-Review. President Gray was the reviewing official and Professor Drake distributed an invitation for the faculty to attend. President Gray also toured a Navy combatant at Newport, Rhode Island as did members of the MIT Faculty ROTC Committee. Midshipmen participated in summer training aboard Navy vessels and a number served aboard vessels of foreign navies. Sail training aboard the 41 foot sail training vessel Patriot augmented experience available through the Sail Pavilion. An 11-day orientation program at Fort Devens, field trips to Naval Educational and Training Center, Newport, Rhode Island, Naval Air Stations, Pensacola, Florida and South Weymouth, Massachusetts, and Camp Lejeune, North Carolina combined with drills at local campuses provided increased awareness and understanding of military issues.

Personnel changes include Commander John Watkins relieving Commander Ward as Executive Officer, Captain Shafer relieving Captain Taylor and Lieutenant Howlett relieving Lieutenant Josephson as Technical Instructors. Yeoman Senior Chief Petty Officer Kreamer relieved Chief Macleod as Administrative Officer and Quartermaster Petty Officer First Class Clemmons relieved Chief McCracken as Assistant Navigation Instructor.

As I begin my third year as Professor of Naval Science, I anticipate continued development of this program.

CAPTAIN ROBERT W. SHERER

Office of the Dean of the Graduate School

The ODGS underwent a major reorganization during the past year in terms of its structure and personnel. The two associate dean positions were replaced with a single associate dean who was given broad responsibilities over the entire spectrum of the office's activities, and who could, thereby, act with much more authority on behalf of and in partnership with the dean. A new assistant dean's position was created with responsibility for the special needs of minority and women graduate students; this position reports directly to the associate dean. The position of assistant to the dean was expanded to provide assistance to both the dean and associate dean. The new dean's positions were filled by two new members of the ODGS staff, viz., Associate Dean Isaac M. Colbert and Assistant Dean Margaret D. Tyler, respectively. The one continuing member of the ODGS staff, Jackie Sciacca, assumed the expanded position of assistant to the deans. A complete turnover of the ODGS support staff also occurred, with the appointments of Emaline Cornett, Debbie Roebuck, and Juanita Rodrigues. With these changes in place the office entered what we hope will be a long period of stable and efficient operation.

During the past year a major step forward was taken in completing the modernization of computing facilities and practices within the ODGS. Under the leadership of Associate Dean Colbert, we installed a Macintosh-based system which is networked within the office and connects also to the Institute's central administrative computing facility. The entire staff has adapted to the system quickly, and there is evidence that intra-office communication has been greatly enhanced. With this system each staff member has direct access to the Registrar's data base; this access has proven to be particularly valuable in facilitating our acquisition of individual student information and in our inputting of graduate financial support data to the Registrar's data base. The latter function is one of the office's largest single tasks and had suffered because of the limited access provided by our previous facilities. In spite of these computing advances we have not yet achieved our goal of making statistical information readily available to our office from the Registrar's data base.

Some progress was made in our attempts to improve or eliminate the processing of paperwork which flows through the ODGS. One such step involved elimination of almost all of the many requests for tuition adjustments which previously were submitted to the office for approval and implementation. These adjustments had been required because of a difference in the rules which were used by the Registrar in computing the tuition of students who terminated their registration in mid-term and the tuition rules that were applied to research and teaching assistants who terminated their appointments. By bringing the latter rules into conformity with the Registrar's the need for most tuition adjustments was eliminated, thereby relieving departments and the ODGS of an extraneous task. Opportunities for similar improvements in the processing of graduate awards and appointments are needed, but may require major new developments in the networking of individual academic departments to a central data base before they become feasible.

In our concern to help develop a large and academically prepared minority pool for doctoral training in the sciences, the ODGS, in conjunction with the School of Science, continued the Minority Summer Science Research Program in the summer of 1988. The program has three primary objectives: to engage a number of minority undergraduates, who have demonstrated talents and interests in science, in ongoing research activities at MIT; to encourage these developing scientists through seminars and direct contact with internal and external role models; and to provide MIT's faculty and research staff with opportunities to observe, encourage, and mentor the development of minority scientists. An award from the National Science Foundation, under its program of Research Experiences for Undergraduates, defrayed

the majority of costs for this third annual effort. In addition, a number of generous industrial donors contributed one-time gifts to help underwrite the 1988 program, which was expanded from 12 interns a year ago to 16 interns selected from a national applicant pool of 80.

Having now completed three successful summer programs which have brought a total of 36 interns to the MIT campus, we are convinced of the effectiveness of the Minority Summer Science Program. The exposure of these young scholars to the daily routines of research at MIT and the opportunity to meet and interact with important role models has already generated results. Almost all of the program's alumni have chosen to continue with their education in the sciences or medical school. Four of the 36 have matriculated at MIT.

In the summer of 1989 we hope to further expand the number of interns to 20, to secure multi-year funding from governmental and corporate sources, and to involve Whitaker College. For the long term, we hope to secure a stable financial base that will support program activities over a five-year period, gradually expand the number of interns to a maximum of 30, and begin to build a small engineering focused summer effort within the School of Engineering.

A new tax issue of importance to graduate students arose during the past year. In July 1989, the Commonwealth of Massachusetts adopted a tax bill which brought the state income tax law into conformity with federal law. The effect of this action was to make the stipends of all research assistants subject for the first time to state income tax. A portion of fellowships of students who are legal residents of Massachusetts for tax purposes also became subject to the state income tax. A particularly distressing aspect of this new tax law is that it was made retroactive to the beginning of the 1989 calendar year, thereby creating an instant unanticipated tax burden of several hundred dollars on many of our graduate students and giving the Institute no time to make provisions for it. Several departments were able to adjust RA stipends upwards to compensate at least in part for the new tax but the bulk of the tax was absorbed directly by the graduate students. The Graduate School Council mounted a petition drive to seek revision of this legislation and one graduate student, Mr. David Wagger, worked with the State Legislature to draft a bill which would effectively have eliminated the new tax, and another bill was introduced which would have eliminated the retroactive feature of the tax. Mr. Wagger and Dean Perkins both testified on behalf of these bills before the Joint Taxation Committee but no action had been taken on either bill at year's end.

The staff of the ODGS continued to invest a major percentage of their time on graduate student counseling. Much of this counseling effort was of a routine nature dealing with academic procedures, sources of funding, and administration of various programs. However, it seems that an increasing amount of time is spent on personal problems which involve a breakdown of the relationship between a student and his/her faculty advisers. Whether this increase is a temporal aberration or represents a more fundamental change is not yet understood, but this is an issue which the ODGS staff will be watching with interest in the coming year.

One of the most important ongoing activities within the ODGS involves administration of a growing number of graduate fellowship programs. Some of these merely require the processing of external funds to the appropriate students' accounts or the allocation of internal funds to individual departments. Others, such as the Ida Green Fellowships for women graduate students or the An Wang Fellowships for graduate students from the Peoples Republic of China, involve a competitive selection process which is conducted by the ODGS, and special donor relations efforts. From a financial point of view, the largest single group of programs are those funded by federal agencies and private foundations in which the ODGS acts as the local implementing agent for the funding agency. These include fellowship programs of such major sponsors as the National Science Foundation (in which MIT is the second largest recipient among all universities), Office of Naval Research, Department of Education, and the Hertz Foundation. These programs require that the ODGS act to enforce the special policies of each of

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these separate programs on behalf of their sponsoring agency as well as maintaining financial and other administrative records for the sponsor. During the past year two new programs of the latter type have been added, viz., the Howard Hughes Medical Institute Doctoral Program in the Biological Sciences and the National Defense Science and Engineering Fellowships Program of the Department of Defense.

Many of the externally supported fellowship programs pose a problem in that they provide full stipends for the student's support but only a cost of education allowance for the Institute's tuition. Typically, the cost of education allowance is in the range of \$6,000 to \$9,000 while our 12-month academic year tuition for the past year was \$17,850, leaving MIT with a substantial tuition shortfall which has generally been made up from internal institutional sources. In recent years that shortfall has been in the order of \$2 million and is growing as tuition and the number of such programs grows while the cost of education allowances remain fixed by the sponsoring agencies. A modest success was achieved during the past year when the Department of Defense responded to MIT's complaints about the impact of the inadequate cost of education allowance and agreed to change the National Defense Science and Engineering Fellowships to full tuition in the coming year.

The ODGS conducted its fifth annual Workshop for Graduate Teaching Assistants in September. This event, which was attended by about 125 graduate students, has proven to be extremely effective in helping new TA's understand the importance of their teaching role and in preparing them for that role. During this past year we also teamed up with the Office of the Dean for Undergraduate Education to conduct a follow-up session in the January Independent Activities Period.

Individual staff members of the ODGS were active in various Institute and external activities. Dean Perkins assumed chairmanship of the Institute's Foreign Scholarship Committee and was ably assisted in this endeavor by Associate Dean Colbert. A modicum of success was achieved with five of our 11 applicants being selected for Fulbright Scholarships for study abroad. Dean Perkins was elected to the Executive Committee of the Association of Graduate Schools (AGS) in the Association of American Universities, and participated on an AGS committee which is preparing a report on the federal role in graduate education. Dean Colbert served as Co-Chair of the Long Range Planning Committee of the Cambridge Partnership for Public Education. Dean Tyler served as chairperson of the Graduate Management Admissions Council's Minority Projects and Applicant Pool Development Committee.

COMMITTEE ON GRADUATE SCHOOL POLICY (CGSP)

A proposal by Whitaker College to establish a new graduate degree program in the field of toxicology constituted the single most controversial and time consuming issue for the CGSP in the past year. The proposal had its origins in the decision in the previous year to close the Department of Applied Biological Sciences and the move of that department's faculty to the Whitaker College. The CGSP was fully supportive of the academic content of the proposed Toxicology Program but evidenced considerable concern over the concept that a small nondepartmental unit such as that represented by the toxicology faculty should be granted the departmental prerogatives of admitting students, offering a program of subjects, and granting degrees. After much discussion within CGSP and at an Institute faculty meeting it was agreed that the program would be offered by Whitaker College, and that a precedent for the College to admit students and offer degree programs had been set at the time of its establishment and in subsequent decisions which had previously been endorsed by the CGSP. The Toxicology Program was subsequently endorsed by the CGSP and the faculty, and was approved by the Corporation.

The CGSP conducted a detailed review of the Master's Degree Program in Real Estate Development which has been offered on a provisional basis jointly by the Departments of Architecture and of Urban Studies and Planning for the past five years. The CGSP concluded that the program has been successful in attracting a highly capable cohort of students, has achieved many of its original educational goals, and has generated considerable interest in and support from the real estate development community. However, CGSP expressed concern over the program's continued dependence on temporary faculty appointments for major parts of its intellectual and administrative leaderships, and recommended, therefore, that the program be extended for another five year period rather than recommending permanent status. The CGSP recommendation was adopted by the faculty.

A CGSP subcommittee consisting of Professor Ain Sonin (chair), Professor Charles Counselman, III, and Dr. Frederick Bowman, reviewed two particularly difficult student grievances and assisted Dean Perkins in bringing them to a conclusion. The wisdom and effort put into these cases is very much appreciated.

The CGSP also provided invaluable assistance to the Dean in dealing with a number of special issues such as just what constitutes an acceptable graduate thesis, and how to deal with confidentiality questions raised during the year by the Privacy Committee. The CGSP of course carried out its usual functions related to the review of academic performance, the termination of enrollment in a few instances, and the recommending of graduate degrees.

I and my colleagues in the ODGS wish to express our thanks and appreciation to members of the CGSP for their service during the past year. The only member terminating service on the CGSP is Professor Samuel Allen who will be replaced in the coming year by Professor Kenneth C. Russell.

GRADUATE SCHOOL STATISTICS

Statistical information about graduate admissions, enrollments, degrees awarded, and financial support are presented in a series of graphs and tables which follow. The format of these data is different from that which has appeared in these reports in recent years. The new formats have been adopted to make the data presentation simpler and easier to read. In the presentations of financial support data we have elected to count the number of students supported by each category of support in terms of *effective full-time* (EFT) students. This measure is computed by taking the dollars of tuition support in a given category and dividing by the academic year tuition for an individual student, and was adopted to account properly for the many cases in which a student is supported on funds from several different categories. In past reports, students with less than full tuition support from any one source were not counted in tabulations of numbers of students supported by that source. That past practice resulted in an under-tabulation of the numbers of supported students even though the dollars of support were correct.

Comparisons of data from recent years show that applications, admissions, and total enrollment of graduate students have all reached relatively stable levels following a period of rapid growth from the mid-1970's to the mid-1980's. The growth of graduate enrollment relative to undergraduate enrollment has also ceased for the moment with graduate students now representing about 53 percent of the total student population. Women make up about 20 percent of the graduate student population, a figure which has been remarkably constant throughout the decade of the 1980's in spite of large increases in the enrollment of women at the undergraduate level.

The enrollment of underrepresented minority graduate students grew by only 11 students (an increase of 7.4 percent) to a total of 159, compared with 148 for the prior year. Once again, the Department of Urban Studies and Planning produced the largest group (8) of incoming minority graduate students, followed closely by the Department of Mechanical Engineering (6). While Urban Studies' aggressive and innovative recruitment program has produced outstanding results, current and future fiscal constraints affecting the distribution of minority fellowship funds will undoubtedly restrain further growth in the number of incoming minority students.

In other areas we remain anxious about national statistics which show a continuing decrease in recent years in the number of underrepresented minority students completing undergraduate programs or applying to graduate degree programs of any type. Because of the very low number of minority applicants to MIT in science and related graduate programs, there were no new minority graduate students matriculating in several departments in the School of Science during the past year. It is increasingly clear that new, aggressive, and innovative efforts are required if current trends are to be reversed.

FRANK E. PERKINS

	FOREIGN	WOMEN	MINORITY	NEW	NON-RESIDENT	TOTAL
SCHOOL OF ARCH & PLANNING	127	153	36	157	42	445
Architecture	78	67	5	87	13	259
Urban Studies & Planning	49	86	31	70	29	186
SCHOOL OF ENGINEERING	742	342	65	546	28	2249
Aeronautics & Astronautics	65	20	3	52	2	198
Chemical Engineering	75	40	7	41	1	234
Civil Engineering	133	46	5	68	8	248
Elec Eng & Computer Science	143	108	26	163	2	684
Materials Science & Engineering	78	51	3	32	3	198
Mechanical Engineering	135	56	16	117	6	387
Nuclear Engineering	57	14	3	34	3	151
Ocean Engineering	56	7	2	39	3	149
SCHOOL HUMANITIES & SOC SCIENCE	123	99	11	77	65	365
Economics	51	21	6	32	19	135
Linguistics & Philosophy	33	24	1	14	12	70
Political Science	39	52	4	27	34	156
Science, Technology & Society	0	2	0	4	0	4
SCHOOL OF MANAGEMENT	206	88	19	266	10	568
SCHOOL OF SCIENCE	285	258	23	199	30	1106
Applied Biological Sciences	21	32	2	3	0	64
Biology	22	75	0	31	1	191
Chemistry	38	62	8	48	6	234
Earth, Atmosph & Planetary Sci	42	43	0	36	6	177
Mathematics	59	18	1	24	12	135
Physics	103	28	12	57	5	305
WHITAKER COLLEGE	10	16	2	11	0	60
Brain & Cognitive Sciences	10	15	2	11	0	54
Health Policy & Management	0	1	0	0	0	6
HEALTH SCIENCES & TECHNOLOGY	5	7	3	3	0	29
TOTAL GRADUATE ENROLLMENT	1498	963	159	1259	175	4822
 CATEGORY AS % OF TOTAL	31.1%	20.0%	3.3%	26.1%	3.6%	

"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 1988

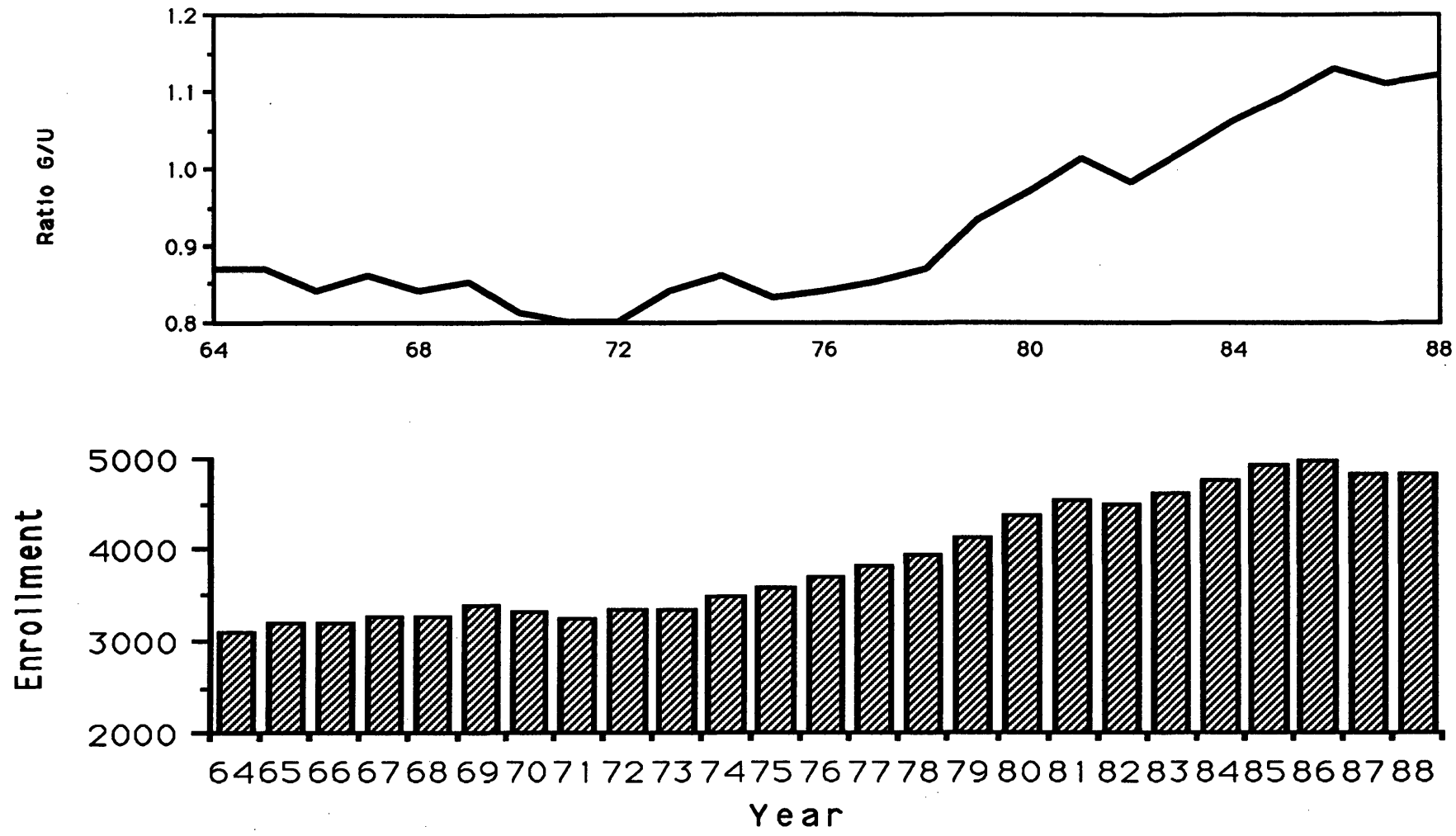


FIGURE 1: 25-YEAR GRADUATE ENROLLMENT HISTORY & RATIO OF GRADUATE (G) TO UNDERGRADUATE (U) ENROLLMENTS.

Category of Support	No. of Students (Actual)	No. of Students (EFS)	Tuition		Stipend		Total Academic Year Support
			Fall Term	Spring Term	Fall Term	Spring Term	
Research Assistantships	2,697	1,952	13,078	12,967	8,489	8,512	43,046
Teaching Assistantships	774	453	3,034	2,902	2,123	2,093	10,152
Graduate Instructorships	17	9	59	67	179	110	415
Federal Fellowships/Traineeships	357	214	1,434	1,455	1,112	1,130	5,131
MIT Endowed Support (Dept'l)	173	79	526	635	292	334	1,787
MIT Endowed Support (ODGS)	57	64	432	329	83	91	935
MIT General Support	475	326	2,182	2,259	733	858	6,032
Industrial Fellowships	244	164	1,098	896	932	919	3,845
Foundation Fellowships	201	96	644	672	500	468	2,284
Billed by MIT to Outside Sponsors	443	422	2,828	2,631	0	0	5,459
TOTAL IDENTIFIED SUPPORT	5,438	3,778	25,315	24,813	14,443	14,515	79,086

Note: Many students receive partial support from one or more sources. Therefore, the total number of students receiving support from any source may exceed the total number of graduate students. The term "EFS" refers to an equivalent number of fully supported students, and is computed by dividing the total fall term tuition support by the fall term tuition of \$6,700 per student.

TABLE II: SOURCES AND AMOUNTS OF GRADUATE STUDENT SUPPORT, 1988-89 ACADEMIC YEAR

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	NUMBER OF APPLICANTS	NUMBER ADMITTED	RATIO ADMIT/APPL	NUMBER REGISTERED	RATIO REG/ADMIT
SCHOOL OF ARCH & PLANNING	971	277	0.29	164	0.59
Architecture	580	154	0.27	90	0.58
Urban Studies & Planning	276	123	0.45	74	0.60
Real Estate Development **	115				
SCHOOL OF ENGINEERING	3370	921	0.27	471	0.51
Aeronautics & Astronautics	277	100	0.36	47	0.47
Chemical Engineering	203	77	0.38	43	0.56
Civil Engineering	319	165	0.52	72	0.44
Elec Eng & Computer Science	1681	220	0.13	125	0.57
Materials Science & Engineering	221	54	0.24	26	0.48
Mechanical Engineering	459	199	0.43	107	0.54
Nuclear Engineering	82	63	0.77	35	0.56
Ocean Engineering	91	43	0.47	16	0.37
Technology & Policy **	31				
Transportation Studies **	6				
SCHOOL HUMANITIES & SOC SCIENCE	718	170	0.24	80	0.47
Economics	368	61	0.17	31	0.51
Linguistics & Philosophy	131	26	0.20	15	0.58
Political Science	202	77	0.38	30	0.39
Science, Technology & Society	17	6	0.35	4	0.67
SCHOOL OF MANAGEMENT	1915	400	0.21	190	0.48
Operations Research **	57				
SCHOOL OF SCIENCE	1713	476	0.28	186	0.39
Applied Biological Sciences	101	3	0.03	3	1.00
Biology	366	74	0.20	29	0.39
Chemistry	294	132	0.45	48	0.36
Earth, Atmosph & Planetary Sci	160	49	0.31	31	0.63
Mathematics	247	59	0.24	23	0.39
Physics	545	159	0.29	52	0.33
WHITAKER COLLEGE	166	26	0.16	13	0.50
Brain & Cognitive Sciences	165	25	0.15	12	0.48
Health Policy & Management	1	1	1.00	1	1.00
HEALTH SCIENCES & TECHNOLOGY	20	1	0.05	0	0.00
INSTITUTE TOTALS	8873	2271	0.26	1104	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 1988

	NUMBER OF INDICATED DEGREES				
	Ph.D.	Sc.D.	Engineers	Masters	Total
SCHOOL OF ARCH & PLANNING	8	-	-	167	175
Architecture	3	-	-	103	106
Urban Studies & Planning	5	-	-	64	69
SCHOOL OF ENGINEERING	199	34	41	562	836
Aeronautics & Astronautics	12	2	0	51	65
Chemical Engineering	25	4	0	37	66
Civil Engineering	20	5	2	75	102
Elec Eng & Comp Science	55	4	16	195	270
Materials Sci & Engineering	27	7	0	33	67
Mechanical Engineering	36	12	1	116	165
Nuclear Engineering	13	0	3	29	45
Ocean Engineering	11	0	19	26	56
SCHOOL HUMANITIES & SOC SCIENCE	47	-	-	24	71
Economics	27	-	-	2	29
Linguistics & Philosophy	8	-	-	2	10
Political Science	12	-	-	20	32
Science, Technology & Society	0	-	-	0	0
SCHOOL OF MANAGEMENT	9	-	-	284	293
SCHOOL OF SCIENCE	175	2	-	26	203
Applied Biological Sciences	12	0	-	4	16
Biology	27	0	-	5	32
Chemistry	35	1	-	1	37
Earth, Atmosph & Planetary Sci	28	1	-	6	35
Mathematics	34	0	-	2	36
Physics	39	0	-	8	47
WHITAKER COLLEGE	10	-	-	4	14
Brain & Cognitive Sciences	8	-	-	3	11
Toxicology	2	-	-	1	3
HEALTH SCIENCES & TECHNOLOGY	8	-	-	1	9
TOTAL GRADUATE DEGREES	456	36	41	1068	1601

These figures include 30 graduate degrees awarded through the MIT-Woods Hole Oceanographic Institution Joint Program as follows: 21 PhD's (6 in Engineering, 15 in Science), 2 Engineer's, and 7 Master's Degrees (3 in Engineering, 4 in Science).

TABLE IV: GRADUATE DEGREES AWARDED IN ACADEMIC YEAR 1988-89

Lowell Institute School

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.

The 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 Drafting Technology or a Certificate in Electronics Technology.

During 1988-89, LIS offered 34 different courses. The fields of instruction included analog and digital electronics including microprocessors through advanced applications, electronic imaging and machine vision, computer literacy, computer programming in BASIC and C, mechanical drafting, geometric dimensioning and tolerancing, printed circuit board design, blueprint reading, machine tools, alarm technology, scientific glassblowing, housebuilding, and a mechanical engineering review course to prepare candidates for the Registered Professional Engineer examination. In addition, refresher courses were offered in mathematics to support both the drafting and electronics curricula.

New courses were introduced in fundamentals of electronics, semiconductor device fabrication, and telephone electronics. A ten workstation IBM PC-AT computer classroom was established exclusively for LIS instruction. New courses in this facility were offered in AutoCAD, computer graphics, and computer aided circuit board design. In addition, a daytime one-week short course on DOS was given ten times, filling the need for first-level PC users to learn how to manage their machines.

LIS admitted a total of 892 students to its courses in 1988-89. Of those enrolled, 78 percent successfully completed the certificate requirements. Among those who completed courses were 59 MIT employees and four regular MIT students. Eleven students earned the Certificate in Electronics Technology, and four students the Certificate in Drafting Technology.

The past academic year has seen LIS expand its program of unique evening courses which no other Boston area school can match. The high percentage of students who successfully complete their courses indicates that both the subjects offered and the level of instruction are well matched to their needs.

BRUCE D. WEDLOCK

Summer Session

Special Summer Programs

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

Summer 1987 - 1800 registrations in 66 special programs

Summer 1988 - 2146 registrations in 68 special programs

Foreign citizens comprise approximately 12 percent of this registration.

Regular Students

Graduate students comprise 85 percent of the student body in summer. The 1988 registration of 3,138 students was a decrease from 3,155 in 1987.

Upward Bound Program

The MIT/Wellesley Upward Bound Program is a year-round, co-educational, multi-racial, college preparatory program for high school youth who reside or attend school in Cambridge. Currently in its twenty-second year, the Program serves 70 academically promising young men and women from disadvantaged backgrounds. The goal of Upward Bound is twofold; 1) to motivate client high school youths such that they persist on to post-secondary education, and, at the same time, 2) to provide them with the fundamental skills necessary for success at the collegiate level.

To a large extent, the Program is influenced by the research done by psychologist Kurt Lewin and his associates. Lewin's hypothesis was that ego growth and academic performance were closely related. Moreover, he concluded that a developing ego needs to experience success in a warm and personal, structured environment for greatest development, in both a personal and social sense. Lastly, it was determined that this personal and social growth could be achieved through intervention outside of the institutions of family and school.

Upward Bound, through its year-round academic and counseling support programming, represents such an intervention. It has long been established that the effects of failure can be reversed through gradual structured achievement. Moreover, the result of the increasing success is a corresponding increase in the individual's level of aspiration. Upward Bound has met with good success (90+ percent college placement of graduates and 70 percent retention of participants) over much of its twenty-two year history through application of Lewin's theory and careful attention to the impact of Program expectations.

Since much of what students think they can achieve is directly related to what others think they can do, the participants' perceptions of their abilities are, to a significant degree, determined by staff expectations. Thus, and largely due to this quasi parenting relationship, the Program is able to exert a positive influence upon its participants such that their academic persistence continues to increase which results in enhanced college enrollments.

The following is an overview of the Program's operational phases:

SUMMER PROGRAM

The six week summer program, conducted in residence at Wellesley College, is designed to provide the participants with a rigorous academic experience. Classes are taught by experienced high school teachers, and graduate and undergraduate students from MIT, Wellesley College and other local colleges and universities. Upward Bound participants must enroll in three classes, each of which meets for an average of five and one-half hours per week, with three additional hours of supervised study. Also, participants may request or be assigned to tutorials whenever the need arises. Each participant is required to enroll in a Mathematics course, an English course and an elective course (social studies or science). Science electives include; biology, chemistry, physics and computers while Social Studies address United States, Black and World Histories. The Mathematics courses range from arithmetic to calculus and Language Arts courses cover basic english and grammar through research paper writing and literature. Lastly, due to an agreement with the Cambridge Public Schools, students may receive summer school credit for failed courses taken for review.

ACADEMIC YEAR PROGRAM

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

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

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

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

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

COLLEGE REPORT, CLASS OF 1989

One-hundred percent of the Program's graduating seniors have enrolled in the following institutions: Brandeis University, Bunker Hill Community College, Fitchburg State College, Morgan State University and Wellesley College.

RONALD S. CRICHLAW

MIT/WHOI Joint Program in Oceanography and Oceanographic Engineering

On October 1, 1989, Professor Sallie W. Chisholm became the new MIT Director of the Joint Program with the Woods Hole Oceanographic Institution (WHOI). Professor Chisholm, a full professor with the MIT Department of Civil Engineering, succeeds Professor Arthur Baggeroer, who served as Director for five years. With the appointment of Professor Chisholm, the MIT/WHOI Joint Program Office moved to Building 54.

WHOI saw many changes during 1988-89. First, Dr. John Steele stepped down on February 1, 1989 as Director of WHOI, and was succeeded by Dr. Craig Dorman, a former Navy admiral and an alumnus of the Joint Program. Dr. Dorman made two appointments of significant impact to the Joint Program. Dr. Charles Hollister, former Dean of Graduate Studies at WHOI, was appointed Vice-President and Associate Director for External Affairs, and A.L. Peirson was promoted from Assistant Dean to Associate Dean of Graduate Studies. Dr. Dorman is currently Acting Dean of Graduate Studies, but WHOI plans to conduct a nationwide search to fill the position.

In the spring of 1989, WHOI changed the name of its Ocean Engineering Department to the Department of Applied Ocean Physics and Engineering. The new name better reflects the research being conducted in the department.

The Joint Program graduated 30 students in 1988-89; of these, 21 received the doctorate, seven received the Master's degree, and two received the Engineer's degree. The breakdown by discipline is as follows: Chemical Oceanography (6); Biological Oceanography (4); Marine Geology and Geophysics (3); Physical Oceanography (7); and Oceanographic Engineering (10).

Due to the large number of students who graduated this past year, enrollment in the Joint Program dropped to 99 as of June 1989. The projected enrollment estimated for September is 123 students, with 16 in Chemical Oceanography, 20 in Marine Geology and Geophysics, 23 in Biological Oceanography, 31 in Oceanographic Engineering, and 33 in Physical Oceanography.

There were 133 applicants to the Joint Program for 1989-90, a figure slightly lower than that of last year. Forty-five students were admitted to the program; of these, 29 (64%) accepted our offer of admission. Over one-third of the entering class are women, and all but five of the students are in the doctoral program. In addition, four of the entering students were awarded outside fellowships, two of whom were awarded both the NSF and the ONR fellowship. One of our students was awarded an Ida Green Fellowship from MIT.

In September 1988, the Joint Program celebrated its twentieth anniversary. Festivities included day-long talks on current research in oceanography at Kresge Auditorium, which were well-attended by the faculty, staff, and students at both institutions as well as many Joint Program alumni/ae.

In May 1989, the Joint Program had its first outside Advisory Committee review. The review committee consisted of Dr. Owen Phillips, Chairman, Johns Hopkins; Dr. Kenneth MacDonald, UCSB, Dr. William Klemperer, Harvard; Dr. Frank Press, National Academy of Science; Dr. Robert Frosch, General Motors; Dr. Millie Dresselhaus, MIT; Dr. Frank Richter, University of Chicago; Dr. Keith Thompson, Academy of Natural Sciences; and Dr. James Holton, UW. The final report from the review committee was very positive, heralding the program as "a jewel in the crown of both institutions."

SALLIE W. CHISHOLM
MARY ATHANIS

Office of the Dean for Student Affairs

INTRODUCTION

The Office of the Dean for Student Affairs (ODSA) completed another exciting and productive year. The overall focus of the Office has been on enriching the quality of life for all students at the Institute. This has involved improving existing programs, issuing reports on the experiences of specific students groups, and initiating new programs and activities.

The year saw increased interest and involvement of students on several fronts ranging from a successful public service drive by the Class of 1992, to more peer counseling initiatives by students within the Institute Houses, to a peaceful demonstration by a group of minority students concerned about proposed changes to Project Interphase.

In the pages that follow, we have tried to capture the essence of the various programs of the office while keeping in mind the importance of providing basic data that may be important for longitudinal studies.

Center for Public Service

The MIT Center for Public Service, completed its first year of operations under the leadership of Mrs. Virginia Sorenson and a Steering Committee co-chaired by Mrs. Priscilla Gray and Professor Robert Mann. Its purpose is to foster greater awareness and participation by MIT students in public service in the Boston and Cambridge communities. The Center serves as an umbrella organization for the service groups already in existence, as a liaison to local service agencies, and as a resource to groups and individuals interested in getting involved in service. Temporarily housed in the Technology Community Association's office, the Center's staff consists of a full-time coordinator, a half-time senior office assistant, and a student intern. The costs of the Center's activities had to be absorbed in our regular budget this year.

The Center currently has over 80 listings of volunteer opportunities in the Greater Boston area covering issues such as hunger and homelessness; education and literacy; elderly, health and medical care; and underprivileged youth. In January, the Center held a Public Service Midway to familiarize the MIT community with the opportunities available for service.

In addition to matching students with volunteer opportunities, the Center has surveyed student activities and living groups to see what service is currently taking place at MIT. The survey revealed that 53% of the groups are already involved in service, and another 27% would like to start. This indicates the encouraging extent to which MIT students are interested or involved in service.

The Center assisted the Class of 1992 with the Freshman Community Service Drive, in which almost 200 freshmen and upperclassmen each pledged to do at least two hours of community service. Many fulfilled this obligation by participating in the Walk for Hunger and the Boston Hunger Cleanup. The Center sponsored an extremely successful clothing drive, collecting eight vanloads of clothes for five homeless shelters in Boston and Cambridge. In addition, the Center held a dinner forum entitled "National Public Service: The Prospects" which was attended by over 100 members of the MIT community.

Among the Center's future plans are a Public Service Project Day during R/O week, a modest number of IAP and summer internships, forums, and a newsletter of current service news and volunteer opportunities. In addition, plans are being developed for three IAP seminars: a public service sampler, an examination of the politics of the welfare state, and a seminar in which students plan and teach a science/engineering design class to underprivileged elementary school students. The Center plans to work with Project Athena to have volunteer opportunities listed on the Athena Network.

International Issues Group

The International Issues Group (IIG), which Dean McBay chairs, has been examining issues of concern to international students over the past two years. During this time, discussions have been held with international students and with faculty and administrators who are responsible in some way for providing services to these students. In addition, the IIG has conducted two studies to learn more about the concerns of international students and whether existing programs and student support services are meeting their needs.

The first study, a survey of departments, laboratories, and research centers, indicated that administrators and faculty did not feel that international students presented any major problems; however, people did feel that when there were problems, they generally involved language difficulties, finding adequate housing (temporary or permanent), or financial pressures. The second study, a survey of international students conducted by Dean Alberta Lipson, reiterated the above findings and highlighted some additional concerns -- including the need for improved international graduate student orientation programs; the importance of buddy systems for newly-

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arriving international students; the necessity of having someone in each department act as a centralized information resource for international students; the need for facilities and programming that would facilitate social interaction between American and international students; and additional staff for the International Students' Office.

Study findings have been disseminated in various ways -- through written reports, discussion with the Visiting Committee on Student Affairs, and meetings with faculty and staff. The IIG will also send a final report to the Provost listing recommendations that the group feels are warranted based on its deliberations and the studies it has undertaken.

Minority Student Issues Group

In March 1989, the Minority Student Issues Group (MSIG) released its second report entitled The Recruitment and Retention of Minority Students At MIT. The report focused on recruitment, admissions, financial aid, and the various other support services available to minority students at the Institute. It was distributed to each faculty member and made available, upon request, to other members of the MIT community. In addition, copies were sent in response to numerous external requests.

The report highlighted improvements on several fronts since the release of the Committee's first report, The Racial Climate on the MIT Campus. These improvements result from the leadership of President Paul Gray and Provost John Deutch as well as the efforts of several concerned faculty, staff, and students. Highlighting the concerns raised in the report were the differences in academic performance and graduation rates between underrepresented minority students and their non-minority peers. Specific recommendations were made to address these problems including changes in Project Interphase, greater emphasis on cooperative learning, and increased faculty interest in minority students and their performance.

The third and final report of the MSIG will focus on the recruitment and retention of minority faculty at MIT. It is being prepared under the leadership of Professors Ken Manning and Arthur Smith, and is expected to be released this fall. The S-MSIG continued to meet this year as well, providing a forum for discussion of issues of concern to students and a means of getting student feedback on new efforts on behalf of minority students.

The Quality Education for Minorities Project

More than 35 years after Brown v. Board of Education, and despite nearly a decade of education reform, most of the nation's 13 million underrepresented minority students are still relegated to separate and unequal schools and an inferior education caused by our two-tiered educational system. It is becoming increasingly evident that the lack of educational opportunity for minority students further damages America's position in an increasingly competitive world economy. As we prepare for a century in which minority Americans will represent one-third of our population and in which educational requirements for the majority of the labor force will significantly increase, a comprehensive, national plan to improve education for minorities is sorely needed.

The Carnegie Corporation of New York has awarded almost \$2 million to MIT to prepare such a plan through the Quality Education for Minorities (QEM) Project which is directed by Dean McBay. The project will release its Action Plan in January 1990 which will be designed to improve education for American Indian, Black, Mexican American, Native Alaskan, and Puerto Rican students along the educational pipeline.

Dr. Richard Hope, Executive Director of the Project, is responsible for the day-to-day operation of the Project and we are advised by a 37-member Action Council for Minority Education. The Action Council is chaired by University of Texas at Austin Professor Ray Marshall, former U.S. Secretary of Labor, and includes President Paul Gray and Corporation Chairman David Saxon. Additional support is provided by a 16-member Resource Group that meets regularly with the Project staff and by the MIT Student Resource Group, a 15-member group of MIT undergraduates. The Student Resource Group will be working over the summer on significant aspects of the Action Plan.

The Action Plan's recommendations will be based upon the findings of nine regional meetings involving policymakers, educators, parents, and students, as well as a series of focused discussions held at MIT with prominent educators and academic experts.

Following the release of the Action Plan, the QEM Project will establish a non-profit organization to implement key recommendations from the Action Plan through a series of demonstration projects. Special emphasis will be in areas such as producing more minority mathematics and science teachers and university scholars, creating residential academies for minority youngsters, and rekindling a faith in education among minority communities. It will also provide research and evaluation assistance to other minority education intervention projects, and will continue to serve in a convening/facilitating role for various groups and projects concerned with minority education.

Other Major Developments

The Independent Living Group Review Committee, chaired by Professor Robert Kennedy, submitted its report in December. In view of the changing demographic composition of MIT's student body, a major recommendation of the Committee was that the Institute begin now to plan for the acquisition of additional undergraduate residential facilities or risk having to abandon our current housing policy. The Committee's report has been made available to the Freshman Housing Committee, created by the Provost, for use in its deliberations.

After nine very successful years as Housemasters of Baker House, Harold and Irene Reiche will be leaving their positions in August. We are very grateful to the Reiches for their many contributions within Baker as well as to our monthly Housemaster discussions. Will and Myra Watson have been appointed as the new Housemasters at Baker. Professor Watson is a member of the History faculty.

We were very pleased this year to welcome Patricia Kaurouma as Director of the Office of Minority Education and Associate Dean for Student Affairs, and to have Steven Burke join us in the Central Office as Assistant to the Dean. Dean Kaurouma shares our goals of achieving increased academic excellence among minority students and of increasing faculty expectations of and involvement with minority students.

Mr. Burke has worked with MIT Information Systems to develop an Apple Macintosh local area network for the Office. The network will be used to help facilitate the sharing of information among staff members through document circulation and multi-user databases. Administrative and Support Staff members have praised the changes and we have already seen a significant rise in productivity across the various sections. The most notable has been the support to the International Students' Office where there has been a significant increase in workload due to recent changes in US immigration laws.

Affirmative Action Successes and Objectives

The ODSA continued to maintain a strong commitment to Affirmative Action during the year, with a staff that was 22% minority and 32% male. There was a percentage drop in minority representation resulting from the transfer of staff (including two minority males) to the Campus Activities Complex in the Operations Area. The following table reflects the race/ethnicity and gender profile, as of June 30, 1989 of the 45 full- and part-time positions in the ODSA:

	Minorities	Non-Minorities	Total
Administrative & Academic Staff			
Male	2	9	11
Female	5	15	20
Subtotal	7	24	31
Support Staff			
Male	0	0	0
Female	3	11	14
Subtotal	3	11	14
TOTAL	10	35	45

The 2 minority men in the administrative and academic staff category include 1 Black and 1 Mexican American. The 5 minority women in this category are Black. Not included in these numbers is the Dean-on-call who is a Black male or the Quality Education for Minorities Staff which includes 1 Black male and 3 Black females. Of the 3 minority females among the 14 support staff members, 2 are Black and 1 is Asian.

These figures also do not include an additional Black female who has been hired as a replacement, but will not join the staff until Fiscal Year 1990. During Fiscal Year 1989, minorities and males together represented 25% (1 minority and 1 male) of the new full- and part-time persons hired. The hiring of at least 1 Asian American to the full-time Administrative Staff remains as a goal for Fiscal Year 1990.

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

SHIRLEY M. MCBAY

Central
MARILYN BODNAR
STEVEN BURKE
ALBERTA LIPSON
VIRGINIA SORENSON
BETTY SULTAN

QEM Project
RICHARD HOPE
PAUL GOODWIN
TRACY ROBINSON
KEVA WRIGHT

UNDERGRADUATE ACADEMIC SUPPORT

The Undergraduate Academic Support (UAS) Office coordinates the freshman and undesignated sophomore advising programs, oversees the orientation programs for all new undergraduates, and serves as an academic information center for students, faculty members, and departments. The office also serves as the administrative support structure for the Faculty Committee on Academic Performance (CAP), Undergraduate Seminars, the January Independent Activities Period (IAP), and the Wellesley-MIT Exchange Program.

During 1988-89, in addition to maintaining its established administrative functions, UAS advanced its effort to: 1) empower the freshman advising system; 2) foster friendship and closer working relations between UAS staff and various student organizations and living groups; 3) extend the variety of learning opportunities available to undergraduates during IAP and involve first-year students more consistently as active IAP participants; 4) improve the organization, schedule, and academic emphasis of the Residence/Orientation period; and 5) implement an experimental system of residence-based peer tutoring.

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

Freshman Advising Program

The primary counseling of freshmen during 1988-89 was carried out by 221 advisors, including 135 faculty, 12 instructors/lecturers, 7 research staff, 20 graduate students, and 47 administrative staff. Supporting these advisors were 230 undergraduates who served as associate advisors. It is worth noting that this year 61% of all advisors were faculty members, an increase of 11% over 1987-88.

We are carrying forward a number of measures designed to improve the quality of advising, including: a) a consolidation of advising under those who do it willingly and well; b) inculcation of a new attitude toward the advisor's role, with emphasis on intensive and frequent contact and attentiveness to a wider spectrum of the advisee's needs; and c) encouragement of group meetings with advisees, to complement one-on-one sessions, not only within the framework of Freshman Advisor Seminars (see Freshman Initiatives below) but across the board, as the number of advisees per advisor increases.

In addition, we are continuing our effort to keep advisors better informed and supported through various orientation programs, streamlining the paperflow, the revised and augmented Advisor's Guide, refinement of the Freshman Watch (the early warning system which alerts advisors to advisees experiencing academic difficulty), and modest support for special events involving advisees and advisors.

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

Academic Year	Required Withdrawals	CAP Warnings	UAS Letters	Total Academic Actions
1988-89	14	107	82	203
1987-88	10	91	91	192
1986-87	8	91	84	183
1985-86	10	94	73	177
1984-85	13	79	53	145

Undesignated Sophomore Advising Program

Twenty-four faculty and staff advisors counseled the 65 students who chose not to declare a major at the beginning of their sophomore year. By the spring term, the number of undesignated sophomores had decreased to 15. The respective fall and spring student figures for 1987-88 were 93 and 20. This significant decrease in the number of undesignated sophomores suggests that emphasis on early selection of a major field may be growing stronger.

Residence/Orientation

Each fall's Residence/Orientation (R/O) Program for new undergraduates is produced by students in collaboration with UAS and other ODSA staff. This year's R/O was coordinated by F. Curtis Jones '89, assisted by Anne Louit '90 and Pamela Barrett '90.

Useful changes in the traditional R/O format included 1) turning the pre-rush orientation sessions over entirely to upperclass student discussion leaders, without faculty or staff participation (a freer, less inhibited exchange of questions and views resulted); 2) releasing advisors and administrative staff from any obligation to attend the pre-rush freshman picnic, thus helping to effect a clearer distinction between the residence selection and academic orientation components of R/O; and 3) introduction of a mid-week Advisor/Advisee Day, to launch academic orientation, featuring the first "advisor rush" and advisor/advisees picnic on Kresge Oval.

Book Night (initiated in 1987 as "The Great Cane Debate") centered this year on Toni Morrison's novel Beloved. Nearly the entire entering class attended a multi-media dramatic presentation in Kresge, including audience participation. This was followed by dinner-discussions of the book in all but one of MIT's 46 living groups. More than a hundred faculty and administrative staff participated as guest discussion-leaders.

Administrative Support to the Committee on Academic Performance

The Committee on Academic Performance (CAP) was chaired this year by Professor Stanley Kowalski. During the year, the Committee handled approximately 380 petitions from individual students requesting readmission and exceptions to certain regulations of the faculty. A total of 66 Required Withdrawals (representing about 1.5 percent of all undergraduates) and 327 Warnings (approximately 7.5 percent) were voted for the academic year, distributed by class as follows.

Class of	Required Withdrawals	CAP Warnings
1989	12	52
1990	26	68
1991	14	100
1992	14	107

Freshman Advisor Seminars

There was a significant increase this Fall in the number of Freshman Advisor Seminars; 65 advisor seminars accommodated nearly 600 of the 720 freshmen who applied for them. Twenty four of the Institute's 28 academic departments were represented. For Fall 1989, there will be 52 Advisor Seminars, representing 20 academic departments.

Residence-Based Advising

The advisory clusters in Baker House and 500 Memorial Drive did well this year. In Baker, 9 advisors and 38 associate advisors served 43 advisees; in 500, the numbers in each category were 5, 20, and 30 respectively. As part of our effort to have residence-based freshman advising in all of the dormitories, New House is in the process of recruiting faculty advisors and associate advisors for the coming year.

New Initiatives

This year there were two new significant ventures in the living groups, each of them generated in large part out of student initiative and concern, and each with the goal of improving community well-being for students generally and for freshmen in particular: 1) A system of Junior Advisors in East Campus to provide companionship and personal support to the dormitory's freshmen. There were 27 Junior Advisors (chosen from the junior class), each assigned 3-4 freshmen, so that each of the 100 freshmen assigned to the dorm had a Junior Advisor. This program successfully encouraged intra-dorm activity; 2) McCormick Hall, the only all-women's dormitory, instituted a Big Sister/Little Sister program, with 48 upperclasswomen serving as Big Sisters to 75 Little Sisters. The goal for the

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next year is to enroll all the freshmen assigned to the dorm to a Big Sister. Although programs like these need continuous support and tactful ODSA linkage in order to reach their full potential, they represent a promising development in students' efforts to enhance the quality of life in MIT's residential system.

Independent Activities Period

In 1988-89 UAS staff worked closely with the Independent Activities Period (IAP) Policy Committee (under its new chair, Professor James Mar) to implement, on an experimental basis, a number of measures designed to heighten student awareness of the diverse opportunities for new styles of learning during IAP: 1) an IAP '89 Preview was published as a Tech Talk supplement in early October, alerting students to major activities upcoming in January; 2) the number of sustained and/or credit-bearing activities offered by departments was increased by about thirty percent; these offerings were generally well-subscribed and popular, suggesting that there is significant student demand for this type of intensive learning experience during IAP; and 3) freshmen, working with their advisors, engaged in more formal early planning of their time-commitments during IAP.

The total number of scheduled activities for IAP '89 was 685 (up from 589 the previous year). More significantly, there was a promising decrease from 60% to 52% in the number of activities that met only once.

The Policy Committee and UAS Staff with the assistance of Dean Alberta Lipson are conducting a full study of patterns of student/faculty involvement and opinion regarding IAP during the two-year experimental period. The results should be useful to the CUP and the MIT faculty in determining what directions IAP might usefully follow in the long run.

The Undergraduate Seminar Program

There were 48 Undergraduate Seminars for fall term, including 20 "hybrid" seminars admitting both freshman advisees and other students, and 41 seminars in the Spring for a combined total of 89 for both semesters, with total undergraduate registration of 1,015. This Spring there were 13 House Seminars (up from last year's 7), hosted by 4 residence halls and 9 independent living groups, enrolling 162 students of whom 24 were freshmen. While the total number of Undergraduate Seminars was lower than last year, the percentage of enrollment rose.

The MIT Colloquium

After a year's hiatus, the Colloquium was revived in 1988-89 with two well-received events that attracted unprecedentedly large numbers of people from all quarters of the MIT community. Strong attendance by undergraduate students - a goal sought but never achieved in earlier Colloquia - was made possible by a new organizational structure in which leaders from the Dormitory Council, the Interfraternity Conference, and the Student Committee on Educational Policy assumed much of the direct responsibility for planning and implementation.

In October, "How to Be Good" focused on ethics in MIT education. Professors Noam Chomsky, Philip Morrison and Sheila Widnall addressed an overflow gathering of 800 in the Sala de Puerto Rico. "How to Be Different," offered in April, drew 1,000 to Kresge Auditorium as Professors Tunney Lee, William Siebert and Jeremy Wolfe spoke about aspects of MIT's distinctiveness as an educational institution. Each of these events was followed by dinner discussions hosted by more than 30 living groups, and involving close to 150 faculty, staff, and alumni.

Wellesley-MIT Exchange

The Wellesley-MIT Exchange Program's twentieth year was characterized by a moderation in the decline in cross-registration enrollments. The program remains an important educational resource for students at both schools.

In 1988-89, 206 MIT students registered for 253 Wellesley subjects, as compared with 348 MIT students in 370 Wellesley subjects during 1987-88. However, taking into account that the 1987-88 figure includes 172 MIT enrollments in Wellesley Japanese language subjects, offered in 1988-89 for the first time as part of the MIT curriculum, an apparent loss effectively becomes a marginal gain. Corresponding figures for traffic in the other direction show 250 Wellesley students taking 320 MIT subjects in 1988-89, down from totals of 278 and 411, respectively, in the previous year.

One reassuring note is an increase (from 91 last year to 112 in 1988-89) in the numbers of MIT students taking Wellesley subjects on the Wellesley campus. Next year increased publicity will be concerted toward the continuation of this healthy upward trend.

One MIT student earned certification in secondary school teaching through the Education Department at Wellesley. The residence exchange program remained stable, though modest in scale, including about five students from each school.

Under the leadership of Professor Robert Jaffe, MIT co-chair of the Wellesley-MIT Joint Committee, considerable progress has been made in two areas: 1) reducing the size of the Committee itself to more efficient proportions; and 2) working out a new arrangement in which Wellesley and MIT will share the cost of operating the shuttle bus in proportions that more accurately reflect relative levels of actual usage.

Academic Support and Information Center

The Center, located in 7-104, continues to provide general advice and various informative printed material - focused particularly on academic opportunities within all of MIT's fields of study - to increasingly larger numbers of undergraduates.

Pilot Peer-Tutoring Program

This year's small-scale experiment with evening peer-tutoring in Burton-Conner dormitory enjoyed considerable popularity in the Fall term. Four upperclass tutors met regularly with small groups of freshmen for help with conceptual framing and study skills essential to success in several key subjects. Although the effectiveness of this program in the Spring semester was somewhat scattered and more difficult to assess, the undertaking as a whole seems worth continuation and, if funding permits, extension into different living-group settings.

Career and Course Orientation

This effort, too, was vigorously carried forward. The third annual Freshman/Faculty/Alumni Banquet, designed to illuminate students' selection of majors, was a conspicuous success, attracting several hundred freshmen, faculty advisors, and a representative group of alumni.

General

UAS Staff continued to serve on a number of Institute committees. The section also benefitted from close supportive interaction with the Committee on the Undergraduate Program, the Undergraduate Education Office, the Committee on the First Year Program, the Admissions Office, the Office of the Registrar, and the Office of Career Planning and Placement. Close working connections with student groups - particularly the IFC, Dormcon, and UA/SCEP - were expanded in scope. An atmosphere of genuine trust and mutual support is clearly developing.

Staff Changes

Staff changes in 1988-89 included the following: Susanna Hinds left her position as Staff Associate to assume new responsibilities as Director of Campus Activities in the Residence and Campus Activities Section. Her position is now ably filled by Moya Verzhbinsky. Virginia Sorenson, former administrator for seminars and freshman initiatives, has moved on to coordinate the new MIT Center for Public Service. We have been fortunate to replace her with Donna Friedman, formerly of Residence and Campus Activities. Finally, Alice LaPierre is performing admirably in the long-vacant position of Staff Associate for Publications.

The section head would like to note that the UAS staff has achieved this year a remarkable harmony and spirit of friendly cooperation, made even more welcome by their heroic efforts to keep things running smoothly during his own times of difficulty and necessary absence.

TRAVIS MERRITT
MARY ENTERLINE
DONNA FRIEDMAN
ALICE LAPIERRE

JEFFREY MELDMAN
STEPHEN PATTERSON
MOYA VERZHBINSKY
BONNIE WALTERS

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STUDENT ASSISTANCE SERVICES

The year in SAS has been marked by increased expectations of the office in several areas as well as by staff changes. This situation, though stressful, contrasts sharply with last year when the office had to deal with several suicides that taxed the resources, both physical and psychological, of Student Assistance Services. The response to these tragedies was increased awareness and discussion within the community of the need to reach out more to others and to remain alert for signals of distress. Under the leadership of Dean Simonis, a new effort was begun that resulted in the creation of Crisis/Response Teams drawing on the resources of the Medical Department and ODSA. These teams are prepared to provide support to students who are in crisis situations as soon as they are identified.

The primary task of SAS continues to be counselling students, and the ebb and flow of students continued throughout the year. The number of visits from international students increased dramatically as The Office of Immigration and Naturalization Service continued to shift responsibilities from the government to universities and specifically to the International Student Advisor on a given campus. New opportunities for practical training have doubled the interactions with those students who seek work experience in the United States. The implications of these changes are amply illustrated in the report on the quality of life for international students at MIT. The report's findings were discussed with the Visiting Committee for the ODSA and the Committee's recommendations reflect awareness that more is being asked of SAS .

Recent events in China indicate that the expectations in months ahead will continue to outstrip our ability to respond. MIT currently has 180 students from the People's Republic of China enrolled with another 63 admitted for the fall. Of the latter number, 10 can be expected to arrive on campus since they are already in the U.S. Matriculation at MIT for the remainder will depend on financial support and their ability to reach the United States. It is likely that some will not be able to get out of China.

This year was again a difficult year for the Committee on Discipline and Dean Arnold Henderson offered the two different chairs of the Committee exceptional support and advice in dealing with some very difficult cases. Cases heard ranged from academic dishonesty to larceny to disorderly conduct. The Committee finally broke the logjam that had held up cases for unreasonable delays and as the year draws to a close there is only one case pending. Increased efforts by the RCA Section to hear less serious cases have helped ease the pressure on the Committee and have offered all involved quicker resolution to vexing problems. Unfortunately, this has increased the level of stress among the RCA staff.

Work with minority students and women suffered during the Spring term due to the absence of a replacement for Dean Marilyn Braithwaite and to the reduced schedule of Dean Simonis. Lynn Roberson, Staff Assistant for Women Students, increased her hours in an effort to respond to the needs of the growing number of women at MIT. Her efforts included workshops, group presentations, and meetings with departmental women's groups, the women faculty, and the Women Students' Cooperative Board. A study of the quality of life for women students at MIT is being planned under Dean Lipson's leadership for next spring. Support for minority students was continued by Dean Henderson and Dean Tony Canchola-Flores. Both worked extra hard to respond to individual and group needs.

This was a year for continuing successful programs such as Nightline and for initiating new efforts such as "A Place To Go..." with Dr. Margaret Ross of the Medical Department. The latter was an effort to deal with important topics (e.g., stress and relationships) on neutral ground. We began to offer Date Rape Seminars in a format that will be duplicated in the coming year and we have continued to work closely with the Medical Department on AIDS education programs.

Staff Changes

We began the year with a staff vacancy in the International Students' Office and it has been ably filled by Danielle Guichard-Ashbrook. She has brought to the office excellent training, cross-cultural sensitivity, and valuable counseling skills.

Dean Marilyn Braithwaite's departure in mid-year caused concern . She had renewed the vigor of the Section's programs with the minority community and improved our credibility in a remarkable fashion. In addition, Dean Jacqueline Simonis was on medical leave for three months and has worked half time since early April. She will be full-time again in July and the position vacated by Dean Braithwaite has been filled with the appointment of Ms. Ayida Mthembu who will join the staff in August.

ROBERT M. RANDOLPH
DANIELLE GUICHARD-ASHBROOK
ARNOLD HENDERSON
MILENA M. LEVAK

LYNN ROBBERSON
JACQUELINE R. SIMONIS
ANNE ST. ONGE

RESIDENCE AND CAMPUS ACTIVITIES

Undergraduate Housing

The crowding in Institute Houses decreased this year as the number of crowded rooms dropped from 125 in September 1987 to 91 at the beginning of this past fall term. This reduction was due primarily to an increased number of freshmen living in fraternities. The return rate for upperclassmen rose to 97.2% this year, in contrast to 96% last year.

This year's incoming freshman class of 1067 included 35.3% women, 2.7% fewer than last year. While some improvements were made in providing women with a greater range of housing choices, additional single sex housing is needed, including sorority housing.

Campus Activities

Cooperation among the more than 200 recognized student activities was strengthened this year by the merger of undergraduate and graduate organizations into the Association of Student Activities (ASA). The ASA also initiated an annual weeklong leadership conference aimed at addressing issues faced by student leaders.

Under the leadership of Jonathan Katz and Ephraim Lin, the Undergraduate Association (UA) was active in discussions regarding changes to freshman year pass/no record grading and student activity funding policies and procedures. The UA formed ad hoc committees to address undergraduate housing, the alcohol policy, student stress, and food service on campus. In addition, the UA social council revamped Spring Weekend and organized a week of campus-wide collaborative events.

The process for registering alcohol-related events was revised this year in order to better educate party organizers about their responsibility and liability for campus social events. Private parties, whether hosted by students or staff, were also required to register with both the Campus Activities Office and Campus Police. Alcohol education continued this year with the advent of living group based T.I.P.S. (Training for Intervention Procedures by Servers of Alcohol) sessions as well as the IAP IMPACT training workshop on alcohol and drug use.

Assisted by student leaders, the Campus Activities Office developed a multi-media leadership library available to student activity members. Leadership training workshops were also delivered throughout the year to both living groups and student activities.

Graduate Student Housing

On December 30, 1988, a ground-breaking ceremony officially kicked off construction on the new MIT graduate student dormitory at 143 Albany St., which is scheduled to be completed in January 1990. The 185-bed dormitory will house single and married graduate students without children. An additional thirty spaces for single graduate students were added this year with the completion of the renovations to the basement of Ashdown House.

Fraternities/Sororities and Independent Living Groups

Fall 1988 rush results were better than expected with approximately 280 men and women pledging Independent Living Groups (ILGs) and 53 women pledging the two non-residential sororities. Sigma Kappa, a new sorority, completed a successful expansion effort, pledging 82 freshmen. Forty-eight underrepresented minority students pledged ILGs, almost double the number in 1987.

Significant progress was made in the area of property and liability insurance. Twenty three ILGs are currently participating in the Alumni Interfraternity Conference insurance group. The program now provides for full replacement value of the property and \$11,000,000 of general and umbrella liability coverage. Each policy in the program now has a common renewal date of April 10, easing the confusion felt by some house corporations over receiving several bills for insurance during the course of the year. Previous difficulties with houses failing to meet basic life safety standards are being addressed by the hiring of a consultant who will perform an assessment of each of the facilities and develop plans for any necessary improvements. Participation in an ongoing third party inspection program will also become mandatory by 1990.

Improvements were seen in ILG/neighborhood relations in the Back Bay. A series of meetings with representatives from the Mayor's office and the Boston Police Department were held at several fraternities in the Back Bay and no Lodging House License violations were reported by the Licensing Board.

184 Associate Provost for Educational Programs and Policy

The Interfraternity Council (IFC) ratified a new constitution providing for the formation of a President's Council to replace the IFC representatives' meetings. Progress towards a "dry rush" was made when the ILG presidents and rush chairs unanimously agreed to a policy that forbids freshmen to be served, to consume or possess alcohol at anytime in an ILG during rush.

Talbot House

Talbot House has had another year of high visitor activity. The house itself has been maintained with a reasonable maintenance program. The fire alarm system, which had problems last year, functioned well. The house was inspected by the MIT Safety Office in February and the evaluation report noted that most suggestions from previous inspections have been addressed. Remaining suggestions are to reposition some exit signs and to add some escape route diagrams in the bedrooms. The only major maintenance item for the upcoming year is to repaint the house.

Several aspects of the pricing schedule for visitors need to be reconsidered. In particular, the concept of a flat rate per group, rather than a per person, individual rate, should be reviewed. This year several groups cancelled as the group approached its scheduled visit because, under the current policy, when some members of a group drop out, there is an increased financial burden for the remaining group members. The intent of the flat group rate was to encourage more visitors in order to help meet costs; however, Talbot House is now on a break even basis for meals, so it does not benefit from increased number of visitors.

There was also a problem this year with the non-refundable deposit policy; more cancelling groups requested the return of their deposit than in previous years. The pricing policy will be reexamined, while insuring that both the Talbot House operation continues to remain financially solvent and an equitable pricing schedule is in place.

House Fellows Program

The House Fellows Program is now ending the second year of its three year experimental phase. Established to promote greater interaction and sense of community between students in Institute houses and MIT faculty members, there are currently thirty House Fellows, representing all five MIT Schools. They are associated with six dormitories and eight Independent Living Groups. Interactions during the past year have spanned social and cultural events and have ranged from weekly to monthly contact. Both residents and Fellows generally praise the program for providing a type of interaction which would not otherwise occur at MIT. Plans for the third year include increasing the number of House Fellows to living groups who presently do not have them and conducting an evaluation of the three-year experimental phase.

Discipline and Harassment Cases

This year the ODSA heard 47 disciplinary cases with an additional 6 cases pending. This represents a slight drop from the number of cases heard last year. Sanctions ranged from students being required to leave their houses, to community service, to verbal warnings. A report on the student discipline and harassment cases adjudicated by RCA staff during the 1988-89 Academic year is in preparation.

Charges in these cases included assault and battery, destruction of property, alcohol and drug abuse, and disorderly conduct.

Staff Changes

Andrew Eisenmann was promoted from Senior Staff Associate to Assistant Dean. Steven Burke, Administrative Assistant in Campus Activities, has moved to the Central Office after being promoted to the staff position of Assistant to the Dean. Reta Lee retired from her position of Staff Accountant and Sharon Shea was promoted from the position of Senior Office Assistant for Talbot House to Staff Accountant.

FALL 1988 INSTITUTE UNDERGRADUATE HOUSE COUNT
October, 1988

House	FRESH		SOPH		JUNIOR		SENIOR		OTHER		Total		Total	CAP	Vacancies	Crowds
	M	F	M	F	M	F	M	F	M	F	M	F				
Baker	37	42	38	41	39	46	61	35	1	2	176	166	342	337	0	5
Bexley	9	13	9	7	13	25	30	12	1	0	62	57	119	120	1	0
Burton	36	39	52	54	51	52	63	20	0	0	202	165	367	344	0	23
East Campus	58	31	70	33	42	40	72	28	0	0	242	132	374	362	0	12
MacGregor	63	12	46	42	67	1	94	2	0	0	270	57	327	328	1	0
McCormick	0	57	0	52	0	66	0	53	0	1	0	229	229	219	0	10
New House	31	27	36	32	31	19	30	15	0	1	128	94	222	206	0	16
French House	3	4	5	3	2	3	3	2	0	0	13	12	25	24	0	1
German House	2	2	4	2	3	1	6	1	0	0	15	6	21	21	0	0
Russian House	4	4	0	2	1	3	3	1	0	0	8	10	18	18	0	0
Spanish House	3	4	6	1	3	2	4	1	0	0	16	8	24	23	0	1
Random	8	7	14	12	14	11	15	8	0	0	51	38	89	93	4	0
Senior House	29	14	32	16	11	13	30	25	0	0	102	68	170	183	13	0
500 Memorial Drive	46	42	48	37	35	52	70	43	2	0	201	174	375	352	0	23
TOTAL	329	298	360	334	312	334	481	246	4	4	1486	1216	2702	2630	19	91
COMBINED TOTAL		627		694		646		727		8		2702				

MALE/FEMALE RATIOS IN GRADUATE HOUSING - JUNE 1989

SINGLE	MEN	%	WOMEN	%	TOTAL
Ashdown	344	81.8	76	18.2	420
Green	0	0.0	46	100	46
Tang	338	83.7	66	16.3	404
COMBINED SINGLE GRADUATE HOUSING	682	78.4	188	21.6	870
MARRIED					
Eastgate	174	88.3	23	11.7	197
Westgate	189	90.4	20	9.6	209
COMBINED MARRIED GRADUATE HOUSING	363	89.4	43	10.6	406
TOTAL GRADUATE HOUSING	1045	81.9	231	18.1	1276

JAMES R. TEWHEY
NEAL DOROW
ANDREW EISENMANN
STEPHANIE HARRISTON-DIGGS

SUSANNA HINDS
JOHN E. KEEFE
SHARON SHEA

THE OFFICE OF MINORITY EDUCATION

Under new directorship this year, the Office of Minority Education (OME) has reviewed and enhanced existing programmatic efforts, instituted new initiatives, and further extended efforts on behalf of underrepresented minority students. The 1988-89 school year witnessed the admission of the largest underrepresented minority freshman class in the Institute's history - 171 students. In response, the OME staff remained vigilant in its visibility, accessibility, and the quality and number of services offered to minority students and to the general Institute student body. The OME staff continues its involvement in Institute programs and committees.

The highlights of an intensive and productive year follow.

The Working Group in Support of Underrepresented Minority Freshmen

This ad hoc committee exists for the purpose of sharing information and insights about first year underrepresented minority students in the Institute's continuing effort to provide a positive and supportive environment for all students. The Committee, following exploration of an issue, may make specific recommendations to appropriate offices for enhancing the educational experiences of underrepresented minority students. The Committee may also itself take on tasks it feels appropriate to its general objective. The Committee will periodically report to the Minority Student Issues Group (MSIG) on issues that require action and our findings on issues of mutual interest. The Committee is composed of representatives from the OME, the various sections of the ODSA, the Medical Department, and the Dean for Student Affairs. The Committee is co-chaired by the Director of the OME and the Head of the UAS.

Research and Evaluation

During the past year, Dean Alberta Lipson has been conducting an evaluation of Project Interphase '88. In addition, she also administered a survey of Project Interphase alumni -- both those who have graduated from MIT and those who are currently students to learn more about the benefits and long-term effects of the Interphase experience. Plans are also underway for developing an annual profile of minority students which will integrate data from Admissions, Financial Aid, RCA, UAS, and the Registrar. This

information will provide the OME and other support offices with information about changing social, demographic enrollment, and matriculation patterns of minority students. Other research activities being planned include the evaluation of Project Interphase '89 as well as of Project XL '89, an experimental fall program to be offered for the first time during the 1989-90 Academic Year.

Student Leadership

The OME continued its support for minority student leadership development by sponsoring Institute workshops and partially underwriting student participation in external professional engineering and science conferences. Students continue to give voice to their concerns through the student advisory committee to OME.

A partial list of the student activities the OME has supported follows.

Five Native American students attended the annual leadership conference in Texas sponsored by the American Indian Society for Engineers and Scientists.

Deborah Falcone '89 was instrumental in forming the Native American Student Association which gained increased visibility during the year.

The OME, Black Alumni of MIT, and the Black Student Union co-sponsored a dinner for Black students during IAP that helped to facilitate networking with alumni and provided a forum for addressing key life-planning/professional concerns of students.

The Office co-sponsored the participation of several Hispanic students in PACHANGA, a conference held at Thanksgiving for Chicano students attending Ivy League schools. The conference held at Yale this year addressed educational, social, and political concerns of Chicano students in higher education.

OME Programs

The Tutoring Program (TP) continues to attract increasing numbers of students, primarily freshmen. For the fall term, 155 different students made a total of 611 visits, almost twice the number of visits for the previous fall term. Fifty six different courses were tutored by 25 undergraduate and graduate students. For the spring term, 103 students made a total of 331 visits. They were assisted in 41 courses by 23 tutors.

The Strategies and Secrets for Academic Success series (three sessions per term) went well again this year, especially because of increased faculty involvement.

Common Ground, a discussion group, met monthly during the Fall term. During the Spring term the forum became a weekly support group for minority students and it involved OME, SAS, and Medical department staff. The number of students attending the group grew as issues on campus became of increasing concern to minority students. Students are interested in this support group and it will continue next year.

During IAP, the OME sponsored two workshops under the rubric Unlimited Horizons. The workshop titled "Tooling up for Term II: Strategies for Academic Success" constituted a review of the skills needed by freshmen for the second semester. The workshop sought to help students develop their own strategies for a successful second semester. The second workshop featured upperclass students discussing how their UROP projects were obtained and how they evaluated the experience. The notion of the first workshop has been extended and will become the "Skills Development" segment of Project Interphase this summer. It is anticipated that the OME will continue to offer topical workshops or seminars during IAP.

Thank God It's Friday (TGIF) Open House, a weekly social gathering, was resurrected to encourage students to drop by the OME for informal talks and refreshments. Although the event attracted fewer than a hundred students this past term, it has been another important outreach to students and will be continued.

Director's Open Office Hours are scheduled bi-weekly to encourage any student to come by to get acquainted and to discuss any matter informally. Though the student traffic has been very modest, every discussion held has been important and instructive. The Director plans to continue this practice.

The Buddy System has been resurrected. Through this initiative, upperclass students will be selected to serve as sources of academic and social support for minority freshmen.

Twentieth Anniversary of Project Interphase

With support from the Office of the President, several activities took place in recognition and celebration of the Twentieth Anniversary of Project Interphase. On April 21-22 a two-day symposium was held on the campus. The proceedings of the symposium will be published later this calendar year. An oral history of Project Interphase and its precursor, Project Epsilon, has been developed by Angela Perkins, a Community Fellow in the Department of Urban Studies and Planning. This was done through interviews with many of the individuals involved in the establishment of the program. A survey of former Interphase participants was also conducted to get their impressions of the value of the Interphase experience.

The two-day symposium began with a banquet and continued with a series of guest lecturers and alumni and faculty panels. The symposium was attended by 241 registrants and was a resounding success.

Project Interphase

Project Interphase is being modified, beginning with the coming summer, as a result of: 1) data on the performance of minority students, 2) an assessment of instruction in Project Interphase '88, 3) advice from the OME Faculty Advisory Committee and, 4) student concerns. The major changes are as follows:

- there will be one session (an eight week academic orientation to the Institute)
- only physics, mathematics, and writing will be in the curriculum (chemistry will not be offered)
- students will work in small study groups
- students will earn 6 elective credits, instead of 18, upon successful completion of the curriculum
- a skills development unit has been added to the program

These changes are designed to help improve minority student performance, to orient them further towards the notion of excellence, and to aid further in their total adjustment to the Institute.

Project XL

Project XL (pronounced Excel) is a new fall enrichment program that evolved from discussions with student leaders, faculty, and administrators. It is a first term voluntary program for freshmen to be offered for the first time during the 1989-90 Academic Year. Project XL is designed to help students achieve academic excellence at MIT. Students who successfully complete Project XL will receive 6 units of elective credit for participating in a number of academic experiences including small study groups and a lecture/discussion series. Project XL students will enroll for no more than 48 units of credits, including the six hours of credit for participation in the special Project activities.

Staff Changes

Patricia Kaurouma joined the staff as the new Director of the OME and as Associate Dean for Student Affairs.

FALL 1988 ENROLLMENT STATISTICS FOR UNDERREPRESENTED MINORITY STUDENTS

	Native American	Black American	Mexican American	Puerto Rican	Minority Total	All Students	% Minority
Undergraduate	25	246	130	83	484	4,250	11.4
Graduate	5	79	19	19	122	4,745	2.6
Total	30	325	149	102	606	8,995	6.7

PATRICIA KAUROUMA
ANTHONY CANCHOLA-FLORES
ALBERTA LIPSON
MARIA E. RODRIGUES

Facilities Use

FACILITIES USE COMMITTEE

Reporting to the Associate Provost for Educational Policy and Programs, the Facilities Use Committee formulates and implements policy for the use of Institute facilities by recognized MIT groups, guests from off campus, and by non-MIT organizations hosted by Faculty and recognized campus groups.

Chaired by Stephen D. Immerman, Director of Special Services, Office of the Senior Vice President, this year's committee membership included Roderick Arthur, Assistant Athletic Director; Nancyjo Buck, Administrative Assistant, Campus Activities Complex; Melissa Cryder, Senior Staff Assistant, Office of the Special Assistant to the Chairman of the Corporation; Robert Cunkelman, Staff Mechanical Engineer, Physical Plant; Gayle Fitzgerald, Manager of Conference Services; Winston "Pat" Flynn, Associate Registrar, Facilities and Scheduling; Michael Foley, Manager, Campus Activities Complex; Susanna Hinds, Director of Campus Activities; Doreen Morris, Assistant to the Provost and the Senior Vice President; Mary Morrissey, Director of the Information Center and Special Events; Ronald Suduiko, Special Assistant, Office of the Chairman of the Corporation; Ann Vanwart, Senior Office Assistant, Registrar's Office; and Philip Walsh, Director, Campus Activities Complex.

During the 1988-89 year, in addition to a number of smaller meetings, the Institute hosted a week-long seminar on Digital Signal Processors in RISC processor architecture, a reception hosted by Cambridge Mayor Alfred Velluci to honor the Mayor of Monticassino, Italy, a meeting of Dietitians in Business and Industry, the Patriots Classic Bodybuilding and Gold's Classic Bodybuilding competitions, a meeting of the New England Chapter of Battlefield Commission Veterans, a seminar by the SYDA Foundation, the Fifth Annual Symbolics Lisp Users Group Conference, the Team USA Soccer Team Regional Assembly, a concert sponsored by the Baptist Union Church of Cambridge, the X Window System Technical Conference, a meeting of the Committee of 200, Children's Literature New England Conference, New England Show Choir Camp, English/Japanese Exchange Program, American Institute of Foreign Studies Program, Debate Institute, Lord Corporation Symposium on Technology and Society, the Whitehead Institute Annual Symposium, workshop on Neutron Beam Design, Development and Performance for Neutron Capture Therapy, the Massachusetts Problem Solving Bowl, the Annual Massachusetts Science Fair, the Geoplasma Physics Workshop, the Computers and Mathematics II Conference, the Houghton Mifflin Co. Mathematics Conference, the Massachusetts Special Olympics, and the International Conference on Physical-Chemical Hydro-Dynamics.

In addition to the above listed typical facilities use requests, the Facilities Use Committee together with the Provost's Office, frequently deals with issues involving proposals for controversial use of MIT space. As a result, the Office of the Provost is often consulted on a wide range of political, social, and religious issues stemming from questions about facilities use.

Issues raised during FY '89 included Institute poster policy, definitions of sponsorship, event registration and scheduling processes, use of Walker Memorial and the Lobby of Building 13, the impact of the repair schedule of the ice rink on events planned for that facility, Cambridge alcohol licencing and MIT alcohol policy, liability and MIT supervision of events, and internal communication among event support service offices.

STEPHEN D. IMMERMEN

CHAIR OF THE FACULTY

THE FACULTY POLICY COMMITTEE

The Faculty Policy Committee continued work on issues from the previous year, shepherded items for Faculty Meetings, and heard reports from a variety of Institute groups. FPC devoted a substantial portion of its time to carrying out the recommendations of the Committee on Reorganization and Closing of Academic Units, reviewing the Committee on Discipline and MIT's grievance system, reviewing a proposal to decompress the spring term academic calendar, and formulating future agenda items for MIT and its next president.

To implement recommendations of the Committee on Reorganization and Closing of Academic Units, which reviewed the closing of the Department of Applied Biological Sciences last year, the Faculty Policy Committee prepared a series of policy statements and changes in Faculty rules: a statement requiring the appointment of a presidential advisory committee to review proposals to reorganize or close academic units; a statement clarifying the principle that tenure is backed by the Institute; and amendments of Faculty rules to insure that relevant Faculty committees give proper consideration to the effects of proposed program terminations. The Faculty Policy Committee presented these statements to the Faculty at large, which endorsed them as consistent with the recommendations of the Committee on Reorganization and Closing of Academic Units.

The review of the Committee on Discipline, begun last year, was led by Professors Jay Keyser and Kim Vandiver on behalf of the Faculty Policy Committee. They concluded that many problems associated with COD derive from the failure of the community to understand MIT's grievance system and COD's role. They considered topics such as what constitutes due process, whether a student has the right to have an attorney present at a hearing, the form of permanent record of the hearing required, the role of the representative from the Office of the Dean for Student Affairs, timeliness in reviewing cases, committee composition and size, and the relationship with Campus Police. A key issue that surfaced was what a Faculty committee should do when it has doubts about the meaning or the soundness of an Institute policy. The Faculty Policy Committee met with past and present chairs of COD and reviewed a draft report submitted by Professors Keyser and Vandiver. Concurrent with FPC discussions, Professor Keyser convened an ad hoc committee consisting of himself, the Chair of FPC, Chief Anne Glavin, Dr. Mary Rowe, Dean James Tewhey, Professor Kim Vandiver, and Professor Sheila Widnall to meet periodically to discuss grievance issues and decide which cases should go before COD and which should be handled by other areas.

The Chair of the Committee asked FPC members for recommendations about the composition of the Faculty Advisory Committee to the Corporation for the presidential search as well as the issues that MIT and its new president will face. Some of the latter included strategic vision for the Institute, the financial basis of MIT, the position of science and technology in the US, and the role of science and technology in society.

Dr. David Wiley proposed that the tight schedule at the end of the spring term necessitated a review of the academic calendar. He suggested adding time around the reading and exam periods and making up the days by shortening IAP and eliminating some holidays. The Chair convened a subcommittee on this issue which found that there were no simple solutions and proposed three alternatives: 1) revamp the whole academic calendar, 2) tinker with it through minor adjustments, or 3) move Commencement to a later date and add days to the end of the term. Consensus was not reached, and it was suggested that this topic be considered more fully next year.

Throughout the year the Faculty Policy Committee heard reports from Professor Thomas Greytak, FPC's liaison to the Committee on the Undergraduate Program to remain current with CUP's many ongoing activities. Reports were also heard from the following:

- Professor Keith Stolzenbach, Chair of the Committee on Undergraduate Admissions and Financial Aid, reported on CUAFA's review of admissions which focused on admissions history at MIT, the relationship of student

performance and admissions, and the faculty/admissions linkage. FPC members raised many questions about the conclusions of the CUAFA report and the basis for them.

- Professor Lotte Bailyn updated FPC on the survey the Committee on Family and Work constructed for the community. The survey is expected to yield information on family demographics, the needs for services and benefits and knowledge about them as they currently exist, attitudes on family issues, and the impact of policies on career and family choices.
- Professor Joel Moses, Chair of the Ad Hoc Committee on MIT Lincoln Laboratory informed FPC of its charge, which is to inform the President about the advantages and disadvantages of the current relationship between the campus and the Lab and to make suggestions as to whether this relationship should be strengthened, modified, or terminated.
- Mr. Constantine Simonides provided the Committee with information about changes in the MIT retirement plan.

The Faculty Policy Committee endorsed the proposal from the School of Humanities and Social Science to adjust the Course 21 humanities major by allowing designation of major fields on degrees. FPC also encouraged the Committee on Graduate School Policy to approve the degree program in toxicology. Both proposals were voted and accepted by the Faculty.

The Committee thanked departing members Professors Greytak and Anthony Sinskey, and Mssrs. Andreas Bommarius and William McGrath, the graduate student and undergraduate student representatives, respectively.

The outgoing Chair of the Committee, Professor Frieden, welcomed his successor, Professor Henry Jacoby, and expressed his appreciation to the many members of the Faculty and Administration who worked closely with him during his term as Chair of the Faculty.

COMMITTEE ON THE UNDERGRADUATE PROGRAM

For academic year 1988-89, the Committee on the Undergraduate Program viewed its task to be to bring issues and threads together and focus on the process of communicating CUP's agenda to others. This was stated at CUP's first meeting in September and became the theme for the year. The Committee's work focused on preparing proposals for Faculty votes on the first year and the science requirements, hearing from various Institute groups, and continuing work begun the previous year.

CUP received the report from the Committee on the First-Year Program and immediately began to formulate proposals to the Faculty requesting endorsement for the principle of increased flexibility of when undergraduates can take General Institute Requirement subjects and changing grading policies for undergraduates, particularly during the first year. Motions presented at Faculty Meetings generated much discussion, followed quickly by alternative motions for grading. Members of the Faculty defeated the proposal for flexibility. Throughout April and May, CUP brought together dissenting groups in an attempt to unify the proposals. In May, the Faculty accepted an alternative motion that designated Pass as C or better, limited the number of credits freshmen can take, and changed junior-senior Pass/Fail to Pass/No Record. CUP will review these policies in Spring 1994, and report to the Faculty at that time.

The Committee heard frequently from the Co-chair of the Science-Engineering Working Group, Professor David Wormley, a member of CUP. The Working Group made several recommendations regarding the Science Requirements, which CUP then incorporated into a motion for the Faculty to endorse inclusion of biology in the Science Core, revision of the Science Distribution Requirement, and formation of a Committee on the Science Component of the General Institute Requirements. The Faculty accepted the motion, and a two-semester subject

incorporating biology, chemistry, and materials science was given a three-year trial period by the Committee on Curricula.

Other topics that came before the Committee included the following:

- CUP endorsed a request from the School of Humanities and Social Science for degree designations for humanities majors. This proposal was considered consistent with the general goal of the current undergraduate program review to strengthen the role and presence of humanities at MIT and viewed as an appropriate way to recognize the autonomy and intellectual strength of the divisions within humanities. It also balanced the minor designation voted previously by the Faculty.
- Professor Keith Stolzenbach, Chair of the Committee on Undergraduate Admissions and Financial Aid, was a guest of CUP for the year. He reported frequently on CUAFA's review of MIT's admissions policies prior to his final report to the Faculty in May. Professor Francis Low, Chair of the Committee on the Contexts Experiment, solicited opinions and advice from CUP members as his committee began its work, as did Professor Molly Potter, Chair of the Freshman Housing Committee.
- The subcommittee working on Educational Commons Activities devised a planning process for deans and department heads for encouraging faculty participation in a variety of activities. Guidelines for the process were then distributed.
- Dr. David Wiley, also a CUP guest for the year, brought calendar issues to the Committee, in particular, compression at the end of the spring term. He proposed alternatives which were considered by CUP members and which will be considered further next year.

CUP hosted Provost John Deutch who offered his perspective on the CUAFA review, housing, the budget deficit, Project Athena evaluation, Contexts subjects, the advising system, and IAP.

CUP members made two field trips during the year. The first was to Project Athena, where faculty members made effective presentations about the integration of Athena into their classwork. The second was to the Experimental Study Group, undertaken because of CUP's special interest in the experiences of the freshman year and the special bonding that takes place at the three alternative programs. The visit provided a wonderful opportunity for the Committee to leave the meeting table and observe first-hand the special qualities of ESG.

CUP bid farewell to departing members Msrs. Yonald Chery and Alan Davidson (both undergraduate representatives), Dean Jack Kerrebrock, and Professors Thomas Greytak and Donald Schon.

OTHER FACULTY COMMITTEE REPORTS

Chairs of the Faculty committees have submitted summaries of the major agenda items addressed during the past year:

The Committee on Academic Performance (CAP) met regularly during this academic year and dealt with petitions and issues concerning the academic performance of undergraduates. During each term, a large number of individual requests relating to exceptions to established procedures or academic standards were acted upon. These included changes of registration after add or drop dates and changes between pass/fail and grades. At the end of each term, the Committee met with representatives of the Undergraduate Academic Support Office and with departmental academic officers to review the academic records of all undergraduates and to take appropriate action in the cases of students in academic difficulty. The Committee recommended to the Faculty the candidates for Bachelor's degrees.

During the past two years, CAP met several times to discuss the issue of evening exams. The Committee notes that two-hour evening exams are becoming an increasingly common replacement for one-hour in-class exams for

some MIT undergraduate subjects. The Committee developed a set of guidelines designed to maintain the positive features of evening exams while minimizing their negative impacts. Further discussions of these proposed guidelines will take place with other Faculty committees during the next academic year.

The Committee on Curricula (COC) set itself the tasks first of explicitly defining and clearly stating its role and then providing a set of explicit guidelines to assist faculty and other members of the MIT community regarding proposals for undergraduate subjects. This mission was undertaken in response to COC's difficulty in responding to the increasing pace of educational experiments at the Institute without a clearly defined set of responsibilities and procedures. The COC issued its guidelines for evaluations and approval of undergraduate subjects and used the new procedures for the spring term. Other major COC efforts were involved with the continuing evolution of the HASS-D system and the putting into place of several experimental versions of Institute required courses. Because the increased emphasis on interdisciplinary programs requires sufficient breadth on the part of the Committee to assure that all constituencies are adequately represented, it has been recommended that the faculty membership be increased from the current six to ten.

The Committee on Discipline (COD) adjudicated a number of grievances against students brought to the Committee by members of the MIT community. Among these were cases of academic dishonesty, harassment in the form of anonymous letter writing, theft of computer equipment, and unauthorized entrance to a building roof followed by inappropriate behavior. The sanctions included academic probation, expulsion, restitution of financial damages, and participation in alcohol rehabilitation programs. The Committee Chair participated several times with the Faculty Policy Committee in discussions of revisions to the MIT grievance procedure and in discussions of MIT's pornography policy and met regularly with the group of MIT staff who are involved in the grievance procedure across the Institute in order to coordinate activities and share issues and ideas.

The Committee on Faculty-Administration (CFA) met three times during the year and dealt with four matters facing the Institute. The first task of the Committee was to review a proposed unified pension plan, which was brought about by changes in the law making it necessary for the Institute to implement a more equitable retirement plan for all members of the community. There was a lengthy review of the two plans then in place at the Institute as well as a description of the proposed plan. Members of the MIT administration, representatives of the Benefits Office, as well as a representative from the actuarial firm assisting MIT in the creation of the new plan, met with the Committee. After a great deal of discussion about the substance of the changes being made, the Committee recommended that faculty and staff should be informed as soon as possible of the changes in the retirement plan and the pros and cons of the different options available under the plan. The Committee Chairman outlined the plan to the Faculty at its meeting of February 1989.

The Committee also reviewed and endorsed proposed policy changes which had been recommended by the Applied Biological Sciences Report -- the first dealing with the nature of tenure and the second with reorganization or termination of academic departments. These were later approved by Faculty vote.

There was also a discussion of the grievance procedure, most specifically the description of the current process to follow when tenure is not granted. The new policy is intended to clarify the grievance procedure from a legal standpoint so that both the Institute and the individual are well protected.

Probably the most controversial item of the year was the Committee on Graduate School Policy's (CGSP) consideration of a proposal for a new graduate program in Toxicology to be offered under the aegis of Whitaker College. The proposed program, which is essentially an outgrowth of the program which previously existed in the Department of Applied Biological Sciences, was strongly endorsed on intellectual and academic grounds by the CGSP; however, questions were raised concerning the appropriateness of giving degree-granting authority to a non-departmental unit such as has been established for the toxicology faculty. After discussion of this issue in some de-

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tail at an Institute faculty meeting and review of earlier precedents, CGSP endorsed the proposed program which was subsequently approved by the Faculty and Corporation.

CGSP also completed a detailed review of the Master's Degree Program in Real Estate Development which was concluding its initial five-year experimental period. CGSP reported favorably on several aspects of the program, but expressed concern over the absence of permanent faculty in two of the major leadership positions. A five-year continuation was recommended and subsequently approved by the Faculty.

CGSP also reviewed current policy requiring the submission of financial needs analysis forms from all Teaching Assistants, the Research Assistant work-hour requirements which in some departments appeared to be in conflict with Immigration and Naturalization Service rules, and carried out its usual duties associated with the end-of-term reviews of academic performance and awarding of degrees.

The Industrial Liaison Program serves three masters: the Faculty, the companies, and the MIT Development Office, each of which, at times, has a different, sometimes conflicting, priority. The Committee on Industrial Liaison focused on the objectives of the program, with special attention given to closing the perceived gap between ILP Officers and the Faculty, a distancing which has occurred due to the sense that ILP's primary function was development and the creation of general funds. ILP's organization has been broadened to include all facets of Corporate Relations and the Committee's name so changed to reflect that (to the Committee on Corporate Relations).

The Committee on the Library System reviewed steps taken last year to cut non-essential serials and periodicals. The funding problem in that area that had emerged earlier seems now to be less pressing, but the Committee will keep the matter on its agenda for future years. The Committee also reviewed in detail the Library administration's long-range plan covering funding, space allocation, computer use, and relations with other library systems.

The Committee on Nominations dealt with its usual task of providing a slate of nominees for the standing committees of the Faculty, plus -- this year -- nominees for Associate Chair and Secretary. The Committee also met with the Chair of the Faculty to discuss possible appointees to the Faculty Advisory Committee for the presidential search process.

The Committee on Outside Professional Activities considered three cases during the year. Each case concerned obtaining prior approval of the Committee for proposed activities which could involve a faculty member and an external enterprise. The three cases are summarized as follows:

1. A professor wished to hire, as a limited-term consultant in an Institute research project, a staff member from an external enterprise in which the professor was involved as a principal.
2. A professor had submitted a research proposal to an outside company and was anticipating that the company might also hire him as a consultant. He was concerned that he would be required not to use in his research, particularly in research funded by the company, any knowledge gained through such service. He was told that such a prohibition would not apply; however, it was necessary that his research remain of general interest and publicly available and also that any commercial products resulting from his research should be brought to the attention of the MIT Technology Licensing Office.
3. A professor had conducted research which resulted in a commercial product which was the property of the Institute. The professor planned to terminate the research and then to commercialize the product under license from the Institute. No students would be involved in the future venture.

As the problems involved were relatively simple, each of these cases was handled by polling the Committee by mail and telephone; thus the Committee did not meet during the year. In each instance, it was concluded that no substantial conflict of interest or violation of the Institute's guidelines concerning outside professional activities would be likely to arise, and those involved were made more sensitive to the Institute's requirements in this area. In some cases, additional supporting materials detailing the nature of the proposed activities were required to be presented to the Committee.

Concerning the organization of the Committee, the Chair suggested to the incoming Chair of the Faculty that it would be worthwhile to consider increasing the duration of service for a member of this Committee. This is because the low frequency of cases brought before the Committee (typically one to three per year) results in each member seeing a small total number of cases. As a consequence, the opportunities for forming a consensus and set of shared values which have continuity over the years are fewer than are believed to be desirable in order for the Committee to be reliably consistent in its decisions.

The Committee on Student Affairs (CSA) has held meetings at least once a month during the academic year. In addition to active participation from ODSA, there have typically been four or five faculty members and three students at CSA meetings. Key issues for CSA to focus on were identified in initial meetings, and subcommittees were formed last December to pursue these. These subcommittees have been holding meetings in the intervals between meetings of the full Committee. The CSA has, along the way, held discussions with Mr. Robert Weatherall of the Office of Career Services and with a representative group of MIT chaplains. It has also interacted with Dean Shirley McBay's office in ODSA's preparations for the Visiting Committee and participated in visits by the International Issues Group to department heads regarding support services for incoming international graduate students.

The three subcommittees formed last December will be continuing their work into the next year. Their respective foci are: 1) issues of diversity, pluralism, and mutual respect; 2) international student issues; and 3) examination of the role of the chaplaincy.

The concerns of the first subcommittee clearly embrace those of the other two. This group has been aiming at catalyzing campus activities (colloquia, workshops, etc.) related to its concerns. In preparation for this, it has been working on a statement to embody what mutual respect should mean at MIT. It has also met with groups such as the R/O Committee to examine ways in which these concerns can be incorporated into ongoing events and activities.

The second subcommittee has decided to try and bring together various individuals and groups that have a particular interest in the international dimensions of the MIT experience. The initial goal will be the production of a report that describes these dimensions (gathering statistics for MIT, comparisons with other major universities, and so on), and suggests directions for MIT to move. One particular concern is the absence of an international lounge or center that could serve as a focal point for activities that build on MIT's international nature.

Issues that are being considered by the third subcommittee include the chaplaincy's role at MIT, accreditation, communication, responsibility, facilities, and support. The CSA subcommittee on the chaplaincy has moved energetically to fill out the picture here for the benefit of the full CSA, which will in turn decide how to follow up on this next year.

This year the Committee on Undergraduate Admissions and Financial Aid (CUAFA) conducted an intensive review of MIT's admissions policies and procedures. As a result of this review, the Committee recommended increased faculty involvement in admissions, retention of current admissions procedures, and an increased weight on demonstrated capability and interest in mathematics and science in making admissions decisions. The Committee's findings and recommendations were presented in a report to the Faculty in May.

This year the Committee on the Writing Requirement has been actively engaged in the administration of Phase I of the Requirement and in ensuring a smooth transition of responsibility for Phase II to the departments. Major agenda items have covered 1) a review of departmental plans and options for Phase II including Writing Cooperative subject offerings and paper evaluation methods, 2) modification to the Freshman Essay Examination (FEE) to provide a more objective evaluation of Phase I expository writing skills, 3) counseling a number of students returning to the Institute to complete their undergraduate degree, 4) acting on petitions primarily for students who exceeded deadlines for completing Phase I and for returning students who are not exempted from the Requirement, and 5) preparation of a comprehensive guide for students and faculty covering both phases of the Requirement.

The Committee is pleased to report that the majority of students have responded positively to the spirit of the Requirement and to its importance to their careers. Incorporation of Phase II under each department's administrative responsibility has contributed to student acceptance. Phase II is now an integral part of their academic major rather than just another Institute Requirement.

The Harold E. Edgerton Faculty Achievement Award Selection Committee selected Professor John Tsitsiklis of the Electrical Engineering and Computer Science faculty. In giving the award, the selection committee stated that Professor Tsitsiklis ". . . has proven himself an excellent communicator, talented for explaining complex ideas clearly and lucidly and for inspiring the confidence and interest of his graduate and undergraduate students. His research on distribution decision theory and distributed algorithms demonstrated amazing research productivity and showed a unique ability to obtain solutions to complex problems."

The James R. Killian, Jr. Faculty Achievement Award Selection Committee selected Professor Marvin Minsky, Donner Professor of Science. The award citation stated that Professor Minsky ". . . is indeed considered to be one of the founding fathers of Artificial Intelligence and he has exerted a marked influence on the field ever since. Sometimes a gadfly, he has produced a stream of provocative and controversial ideas which have shaped the identity and development of the field."

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: Stanley B. Kowalski (Academic Performance), Lawrence M. Lidsky (Curricula), William T. Peake and Sheila E. Widnall (Discipline), Jack P. Ruina (Faculty-Administration), Nicholas P. Negrofonte (Industrial Liaison), Judith J. Thomson (Library System), Robert V. Whitman (Nominations), Michael W. Golay (Outside Professional Activities), Joseph Ferreira and George C. Verghese (Student Affairs), Keith D. Stolzenbach (Undergraduate Admissions and Financial Aid), Jefferson W. Tester (Writing Requirement), Chryssostomos Chryssostomidis (Edgerton Award Selection), and Stephen H. Crandall (Killian Award Selection).

Bernard J. Frieden
Laura B. Mersky

SCHOOL OF ARCHITECTURE AND PLANNING

Two historic events dramatized changes in the School. Groundbreaking for an expanded Rotch Library of Architecture and Planning occurred on June 6; the Building 7 studio mezzanines, originally built in the 1960s, were demolished.

Physical changes reflected continuing evolution in the School's academic and professional outlook and contributed to the sense at the end of the year of progress on many fronts. Especially heartening were the advances made in fundraising.

Facilities

Construction is now well under way on the expansion of the School's library. Designed by Schwartz/Silver of Boston, the \$6 million project involves renovation of the existing Rotch Library in Building 7 and construction of an adjacent structure containing six levels of stacks and circulation space. The result will be a 27,000-gross-square-foot facility that will more than triple the amount of space at the Rotch location.

The library building project stimulates other opportunities for improving School facilities. Renovation of the adjacent Building 7 studio will provide improved space for the introductory architecture studio subjects. Detailed planning of renovations also began for Buildings N51/52 to accommodate the new visual arts program along with selected design studios and research activities.

Although renovation and expansion contributes to an atmosphere of physical improvement, the School's overall environmental quality has deteriorated so badly that it is detrimentally at odds with our professional commitment to environmental quality. School Council has resolved to intervene with a specific strategy for improvement and maintenance.

Academic Program

The School's new undergraduate visual arts program was practically launched with the arrival in June of Professor Edward Levine as director. The Provost supported a doubling of resources for the program over the next few years along with a corresponding space commitment.

The Department of Architecture acted to expand its ranks of new faculty and recast its curriculum to include more subject requirements for its professional degree. The Department of Urban Studies and Planning began a process of rethinking its mission in terms of prevailing national political conditions. The Media Arts and Sciences section, which will be evaluated as academic program in 1991-1992, expanded its faculty ranks and made important intellectual progress with the development of a required pro-seminar.

The graduate program in real estate development underwent a required five-year review by a subcommittee of the MIT Committee on Graduate School Policy. The subcommittee acknowledged the outstanding success and leadership position of the MSRED program. The subcommittee recommended that continued efforts should be encouraged and reevaluated. Its report concluded, "The program is of high quality, and it attracts motivated students. In view of the potential instability of the program due to the dependence on visiting faculty, the subcommittee recommends that the MSRED program continue on an experimental basis with a review after an additional five years. Additionally, the fact that the degree program is a new program that is based on a single industry suggests also that an

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additional review five years hence is in order."

At the undergraduate level, a very strong interest in architecture subjects and in architecture as a major continued to increase. There was a large but temporary decrease for architecture in HASS enrollments and concentrators, which was caused by the retirement of Professor Richard Filipowski who taught heavily subscribed visual arts subjects. With the inauguration of a new program in the visual arts, and expansion of offerings in the history of art, the department expects an ever larger role in the Institute's undergraduate initiative.

Although the planning department continues to have virtually no undergraduate majors, it substantially increased its HASS enrollments. In addition the department offered one of the Institute's 12 new context subjects. The Media Arts and Sciences section continued to attract a strong contingent of UROP students.

Research

During the year a subcommittee of School Council planned the reorganization of the Laboratory of Architecture of Planning. Beginning in 1989-1990 management of research and special program accounts will be decentralized to the departments. Research development, on a Schoolwide basis, will focus on housing research, which will involve the deployment of professional personnel and seed funds available for Schoolwide use. Michael Joroff assumes the position of Director of Research Development in the Dean's Office.

The Media Laboratory continued its robust expansion of staff and research. Its research volume increased 30 per cent to \$7.1 million. The School's Computer Resource Laboratory engaged a diversified program of research projects and prepared for a major summer program for professionals interested in the use of computerized "geographic information systems" (GIS). With the ending of Project Athena support for the Computer Resource Laboratory, there is an urgent need to find financial support for its important programs.

Financial Support

Steady work in fundraising yielded endowment for four new chairs and an increase in alumni giving. The Dean's Office carried on a program of alumni breakfasts, including three in Boston, one in Chicago and one in Los Angeles. Stellar fundraising by Professor Nicholas Negroponete served to underpin the growth of the new intellectual area of media arts and sciences. Under agreement with the Provost, Negroponete directed the large amounts raised to endowment, enabling the program's call upon the Institute's budget to remain constant.

The School's new chairs for full professorships include: the Muriel and Norman Leventhal Professorship to support a faculty member whose work is concerned with "city building", with a focus on large-scale urban environments (awarded to Professor William Porter); the LEGO Professor of Learning Research funded by Interlego A/S (awarded to Professor Seymour Papert); the Toshiba Professor of Media Arts and Sciences funded by the Toshiba Corporation (awarded to Professor Marvin Minsky). The Asahi Broadcasting Corporation funded the Asahi Broadcasting Corporation Career Development Professor of Media Arts and Sciences (to be awarded to Professor Glorianna Davenport in December 1989).

Community Presence

The School continues to be distinguished among its peer institutions by fostering activities that extend beyond its immediate academic programs and encouraging participation of its members in the public realm.

At the national level, faculty and alumni were involved on both sides of the presidential campaign. Housing research directed by Professor Langley Keyes contributed directly to legislation and national thinking about housing policy. A School effort known as Initiative 2050 brought together a broad spectrum of faculty and researchers with members of the National Capital Planning Commission to explore a collaborative effort to plan for the future of the national capital region and its federal establishment.

At the local level, the planning department sponsored a forum on a comparative review of the city's development, which featured Boston Redevelopment Authority director Stephen Coyle and former BRA director Edward Logue. In early February members of the School's environmental design program collaborated with the Boston Parks and Recreation Department to generate design and policy ideas for unused open space in Boston neighborhoods. The Massachusetts Housing Partnership awarded a challenge grant to the architecture department to help community groups develop affordable housing.

School members and alumni won five out of 13 awards in Boston Visions, a national competition sponsored by the Boston Society of Architects. Eric Knapp, an alumnus of the real estate program, won the first place award of the Builders Association of Boston for his single-family detached development on Nantucket. A documentary film portrait of four homeless men in a Boston shelter, by planning student Jim Kaufmann, was named Outstanding Social Documentary this year by the New England Film and Video foundation.

In the international realm, the East Asian Architecture and Planning Program sponsored a conference on waterfront design in Japan, and a seminar in Seoul, Korea on the planning and design impact of Olympic Games on host cities. The Center for Real Estate Studies assisted the University of Turin with the establishment of a real estate degree program. Valeria Koukoutsis, a student in the History, Theory and Criticism program, shared first place with a collaborating student from Harvard in a nationwide student competition for an international air terminal in Saudi Arabia. A retrospective exhibition in Karlsruhe, West Germany, featured the Center for Advanced Visual Studies and included work by 45 CAVS Fellows.

Of somber international import, the recent political upheaval in China caused the cancellation of our summer term studio in Beijing. With regret but by mutual agreement the biennial Urban Design Studio taught jointly by the School and Tsinghua University was postponed until next summer. In quite a different political arena, the investigations of the U.S. Congress by the Weiss Committee have caused widespread concern in the academic community. Our School is potentially affected because of the very high interest of the Japanese in our media arts and sciences program.

Community Composition

The School's total enrollment increased from 574 to 602 students. Of this total 40 percent were women (up from 37 percent) and 10 percent were under represented minorities (21 percent in Urban Studies and Planning). Allowing for the usual leaves, the numbers of women and minority faculty members are at a level comparable to last year.

JOHN DE MONCHAUX

FACULTY, OTHER ACADEMIC STAFF, AND RESEARCH STAFF -- 1988-1989

	1987-1988				1988-1989			
	Total	Full Time Equivalent	Women	Minority	Total	Full Time Equivalent	Women	Minority
Department of Architecture								
Faculty	25	23.45	3	-	24	23	2	0
Other Academic Staff	39	18.9	7	1	37	23.75	6	0
Research Staff	2	1.5	0	0	2	1.5	0	0
Without Pay	6	4	1	-	4	2.5	2	0
Department of Urban Studies and Planning								
Faculty	27	25.5	5	4	25	23	5	4
Other Academic Staff	19	10.25	5	2	22	14.33	7	4
Research Staff	1	1	-	-	2	1.5	-	-
Without Pay	11	6.5	7	-	23	13.2	9	12
Media Arts and Sciences Section								
Faculty	13	13	3	0	12	12	3	0
Other Academic Staff	7	5.7	2	0	5	4.7	2	0
Research Staff	0	0	0	0	0	0	0	0
Without Pay	6	3	1	0	5	2.25	1	0
Laboratory of Architecture and Planning								
Faculty	-	-	-	-	-	-	-	-
Other Academic Staff	-	-	-	-	1	.25	-	-
Research Staff	2	.40	1	-	2	1	-	-
Without Pay	19	9.95	1	-	8	4	-	-
Media Laboratory								
Research Staff	18	16.62	3	1	23	21.27	5	1
Without Pay	25	19.9	3	-	0	0	0	0
School Totals								
Faculty	65	61.95	11	4	61	58	10	4
Other Academic Staff	65	34.85	14	3	65	43.03	15	4
Research Staff	23	19.52	4	1	6	25.27	0	1
Without Pay	67	43.35	13	7	40	21.95	12	12

STUDENT ENROLLMENT AND COMPOSITION 1988-1989

	<u>Total</u>	<u>Women</u>	<u>Minority</u>	<u>International</u>
<u>Department of Architecture</u>				
Undergraduate	122	67	6	12
M.Arch.	98	36	4	15
S.M.Arch.S.	48	14	0	37
S.M. Vis.S.	7	1	1	2
Ph.D. (resident)	15	5	0	7
S.M. Real Estate Devel.	18	5	1	1
Total Graduate Resident	186	61	6	62
Ph.D. (nonresident)	12	2	0	4
Special Students (nondegree)	4	0	0	0
ARCHITECTURE TOTALS	324	130	12	78
<hr/>				
<u>Department of Urban Studies and Planning</u>				
Undergraduate	4	3	1	1
M.C.P.	100	54	32	41
S.M.Real Estate Devel.	18	8	2	1
Joint M.C.P./M.Arch.	3	1	1	1
Ph.D. (resident)	35	9	4	14
Total Graduate Resident	156	72	39	57
Ph.D. (nonresident)	35	18	4	12
Special Students (nondegree)				
SPURS	15	2	0	15
CFP	0	0	0	0
DUSP TOTALS	210	95	44	85
<hr/>				
<u>Media Arts and Sciences Section</u>				
S.M. (unspecified)	40	8	0	7
Ph.D	24	5	2	1
Special Students	4	2	1	0
MAS TOTALS	68	15	3	8
<hr/>				
<u>School Totals</u>				
Undergraduates	126	70	7	13
Graduate	453	166	51	143
Special Students	23	4	1	15
TOTAL ENROLLMENT	602	240	59	171

Department of Architecture

Professor William Porter began a term as permanent Department Head this year, after serving as Interim Head for 1988-89. The 'Matrix Committee' established last year continued to advise him in matters of department governance. Some important issues of the previous year were addressed and fairly successfully subdued: i.e., budget cuts have been effectuated; curriculum studies advanced substantially in order both to accommodate growing numbers of undergraduates and to fortify the professional program; and rebuilding of the visual arts is well begun with the conclusion of a national search and the appointment of an excellent new faculty member to direct the program.

The aims of departmental change are to strengthen the disciplinary clusters of faculty within the department, to encourage cross fertilization among them, and to form a supportive and sustaining organizational structure. In the past, distinctions between discipline groups and programs have been blurred, with interdisciplinary responsibility as a result sometimes confused. There has been a serious, sustained effort this year to define areas of responsibility so that disciplines will not simply train those students most like themselves, but rather work productively across programs. Structural clarity will help not only to clarify the substantive focus of each discipline group, but will highlight responsibility and raise the quality of teaching and research.

The Building Technology group is well established and making important gains in its second year under the leadership of Professor Leon Glicksman. A first set of new master's students has been enrolled; new subjects started; an undergraduate curriculum defined and fleshed out; two new faculty members appointed and a search for a third person opened. A wide-ranging research program has been initiated, new research sponsors identified, and many projects are underway.

History, Theory and Criticism (HTC) of Art and Architecture continues to be a model group, serving students in all departmental programs, Institute undergraduates, and its own nationally-recognized advanced and doctoral students. The group has developed new subjects specifically for the professional program and has increased its participation in design studio reviews. With the addition of two new outstanding faculty members in the history of art, the structure is in place to accommodate increasing numbers of Institute undergraduates and doctoral students in art history and to interact with the developing visual arts program. Vitality of the new undergraduate Visual Arts program, now in its beginning stages, seems assured by the presence of Professor Edward Levine who came to MIT in late June.

Fresh thinking and new directions in Architectural Design have resulted from intensive work by the Department Head and by committees of the design faculty. The strategy has been devised treats five key issues: faculty and staff structure for the architectural design group; strengthening design curriculum; establishment of stronger connections with practice; clarification of the visitors and overseas programs; and standards of collegiality.

The Environment and Methods group in the faculty has begun to consolidate its offerings through a common faculty colloquium, shared admissions and advising responsibilities, and a plan for further integration of other subjects of instruction and an increase of research activity.

Problems that continue to demand attention and action are: financial aid for our students--unencumbered scholarship aid remains our first priority; improvement of the quality of department space, in particular N51-52 where architectural design and visual arts will be housed in the coming year; faculty chairs; and obtaining seed funds and sponsorship for research.

Changes now being put in place will make MIT very different from other departments of architecture. Linkages to other disciplines and departments at MIT will be strengthened, and academic inquiry as a part of design teaching will be increasingly legitimized. The new organizational structure, coupled with curriculum re-definition and reform, will increase openness to other discipline groups within and outside the department. And for students, many different careers in architecture and art should be opened up and legitimized in our undergraduate, graduate professional, and PhD degree programs.

PROGRAMS

The Department enrolled a total of 290 regular students in its five programs in fall AY 1988-89. The number of undergraduates (122) represents an increase of approximately 10% over last year, continuing a trend into a third year. The graduate student population has been decreased slightly: Master of Architecture (MArch) and SM Visual Studies (SMVS) remain stable in numbers at 98 and 7 respectively. SM Architecture Studies (SMArchS) students were substantially fewer (48) and PhD slightly more numerous (15) than last year.

Studies have been made this year and proposals offered to structure more explicitly both the undergraduate and professional MArch program. Careful attention has been given to maximizing the educational benefits of overlap between undergraduate and graduate students in the MArch program.

Undergraduate enrollments continued to grow substantially--from 72 in 1985-86, to 90 in 1986-87, to 110 in 1987-88, to 122 in 1988-89. We expect this number to level off at a still higher number if the numbers of sophomores electing Course IV remains constant. Furthermore, it is reasonable to assume that the new undergraduate curriculum which we expect to be in place next year will attract more undergraduates.

This increase in undergraduates, coming at a time of steady budget, means both that programs in the Department must be re-examined to see if economies can be made and that the educational content of the undergraduate program overhauled. The latter is long overdue. We consider the increase in enrollment not just a problem to be solved, but a challenge and an opportunity.

Professor Leon Groisser, chairman of the undergraduate program committee, has formulated a new curriculum offering four possible undergraduate majors: architectural design; building technology; visual studies; and history and/or design methods. Each of the majors is based on a set of common required subjects drawn from each of the discipline areas. While the new curriculum will open up possibilities for later specialization other than architectural design, all options preserve the possibility of continuing in graduate professional design programs.

A proposal for redefining the curriculum of the professional Master of Architecture program was drawn up by a student/faculty committee chaired by Thomas Chastain and was adopted by the department to begin with graduate students entering in September 1989. The guiding spirit behind this proposal is to tighten up and structure the program, even at the expense of some of its flexibility and adaptability to each individual student, in order to guarantee better coverage of the wide range of material the graduate architect should know, and in order to take advantage more systematically of the range of disciplines in the department.

In order to provide a common group of experiences and a common base of knowledge for our students, the department is developing a core of required subjects in areas other than architectural design. These will include foundation (first) and platform (advanced) subjects, both designed specifically for students studying to be practicing architects (as against general subjects

in the area). In addition, a required research seminar is being developed for graduate students entering Level II architectural design. Its purpose will be to start students' choosing areas in which they wish to specialize in order to focus their electives and prepare them for carrying out a thesis.

Since these new required foundation and platform and core subjects will be unique to this department, we will not give nearly as much advanced (transfer) credit for undergraduate subjects taken previously. In order not to lengthen the time required to earn our M.Arch. degree (now normally seven semesters), we have decreased the number of subjects required in each area and the number of general professional electives. The result should be a substantially increased focus to the program, greater shared knowledge among students in the program, and greater interaction among faculty of the department.

Research and Advanced Study continued this year to consider the connection of the second master's streams to eventual PhD study. The matrix committee has concluded for the time being that formal PhD programs should be allowed in Building Technology and HTC only, with admission of doctoral candidates in other fields done on a limited and ad hoc basis.

DISCIPLINE GROUPS

Subgroups of the Architectural Design faculty worked this year at two important tasks: a search for a junior faculty member in design and design methods and development of a proposal for a new stream of advanced graduate MArch students. The search was opened in September and concluded after extensive work in May of this year. More than 50 candidates were considered in a two-stage process, which yielded recommendation for the appointment of Thomas Chastain as Assistant Professor.

In parallel with the search, the design faculty examined staffing policy in general, long-range needs for junior faculty, and issues for their responsible career guidance and mentorship. New policy states that Lecturers in architectural design will be part time; they will typically be younger professionals, whose primary loyalty will be to building a practice. The department will not assign them heavy responsibilities outside their specific teaching and workshop roles. Three excellent candidates in the search will be offered appointments as Lecturers under the new understanding of that position.

Discussions also yielded a proposed structure for the discipline group to be begun in the coming academic year. Tenured and non-tenured faculty will be those who take fundamental responsibility for the design program at MIT and who are pursuing a career in which they will make significant contributions to architecture as judged by criteria appropriate to Institute faculty.

Professor Jan Wampler, with a committee made up of Professor William Hubbard, Yim Lim and Renee Chow, have worked through the second semester to define a curriculum for an advanced stream of MArch graduate students. Addition of a group of 12-15 advanced MArch students in a specially designed, topic-focussed stream is part of a strategy to focus and improve design teaching at the advanced level.

As part of the effort to relate more effectively to architectural practice, the department next year will establish a housing design prototype program. We have secured the agreement of a distinguished local architect to direct the program, and Professors Erich Schneider-Wessling and Professor James McKellar, Director of the Center for Real Estate Development will participate.

Visiting design faculty this year included Charles Correa ('55), who taught a portion of a Level III studio in the spring term. Professor Imre Halasz served as faculty host and coordinator for the studio, which also featured a portion taught by Professor Schneider-Wessling. Fall term visitors to the design faculty were Joan Goody, Peter Droege (SMArchS '78) and Judith Chafee, who all taught segments of the fall term Level III studio.

The Building Technology group welcomed two new junior faculty members, hired as the result of an extensive search conducted last year. The new interdisciplinary SM Degree in Building Technology, jointly offered through the Departments of Architecture, Mechanical and Civil Engineering is approved and in place. The research-based educational program combining architecture and state-of-the-art engineering research is unique in the United States. New research initiatives under way in the group include: composite materials for building envelopes, currently sponsored by eight industrial companies; advanced thermal insulations which do not use CFCs, sponsored by Department of Energy (DOE); interior air quality and ventilation, sponsored by National Institute of Standards and Technology (NIST) and the Environmental Protection Agency (EPA); and energy conservation in buildings, sponsored by Electric Power Research Institute (EPRI). Several new undergraduate and graduate subjects were offered this year in building technology in the areas of structures, energy simulation, economics and controls.

Professor Stanford Anderson headed a rather dynamic faculty group in History Theory and Criticism (HTC) this year. Two senior colleagues were on leave in the fall term, two new professors of the history of art began appointments, and four distinguished visitors taught HTC subjects. Maristella Casciato, from the University of Rome, and Edward Kaufman from Columbia were at MIT in the fall term. Professor Casciato taught two subjects: "Housing in Europe 1900-1940" and a seminar on the history of CIAM and the Dutch contribution; Professor Kaufman taught a subject for graduate students on "Functionalism: History, Ideology and Rhetoric." Andrew Morrogh, who taught most recently at the University of Washington, Seattle, and Zeynep Celik, from Columbia, held appointments in the department for the entire year. Professor Morrogh taught the introductory history of architecture survey (4.605) in the fall and two advanced subjects on Roman architecture of the 16th -18th century; Professor Celik taught subjects on the history of Islamic architecture.

The HTC program at MIT pioneered doctoral education in this area within a professional school of architecture (along with University of California, Berkeley and Princeton). We have been fortunate in attracting excellent students and in turn all of our graduates have challenging positions, including academic appointments at such universities as Columbia, Harvard, Cornell, Wesleyan, University of Illinois-Chicago.

It is at least partially the success of this program that has created a new problem. Our competing graduate schools have grown in number (including Harvard) and the old competitors have both enlarged their programs and increased their scholarship offers. For the 1989 fall admission, for the first time, we were out-competed for the best students in our admission pool. We require additional funding to keep our past admissions fully competitive. We also need to add one admission per year in the history of painting and sculpture in order to complement the new initiatives MIT has taken in this area.

The core subject in the Architecture Studies group, "Methods of Inquiry," was revised and taught by Professor Julian Beinart and Lawrence Vale. In the new format, department faculty members

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presented papers on their own work for class discussion and critique. Frans van der Werf, architect from Rotterdam, Holland, visited the Department in the fall to teach Professor John Habraken's subject, "Practice in Thematic Design," and a design workshop for MArch and SMArchS students. Lawrence Vale (SMArchS '88) was appointed Lecturer to teach in the Environmental Design group; Masood Khan (SMArchS '83) joined the Design for Islamic Societies section as a Lecturer. In the spring term, Thomas Piper (SMArchS '75) and Professor Tunney Lee from the Department of Urban Studies taught an urban design studio for architects and planners which focussed on an overall development strategy for East Boston. Building Technology this year joined HTC and Environmental Design in offering a series of public lectures aimed at advanced students in the discipline.

FACULTY

Professor Porter was named the first holder of the Muriel and Norman Leventhal Professorship. The chair was established by the Leventhals to support a faculty member whose work is concerned with "city building," with a focus on large-scale urban environments.

New faculty in 1988-89: James Axley, most recently a Research Engineer at the Building Environment Division of the National Bureau of Standards, and Leslie Norford from Princeton's Center for Energy and Environment Studies, joined the Building Technology group as Associate and Assistant Professor, respectively. Leila Kinney, formerly at Barnard, and Benjamin Buchloh, from SUNY Westbury and the University of Chicago, began appointments as Assistant Professor of the History of Art in the HTC group.

Professor David Friedman was on sabbatical in Italy for the entire year; Professor Francesco Passanti and Professor Habraken were on leave for the fall term.

Awards to faculty: Professor Habraken was recipient of the Association of Collegiate Schools of Architecture Creative Achievement Award for 1989; Special Interest Group in Urban Settlements (SIGUS): Housing and Design, led by Nabeel Hamdi and Reinhard Goethert, received an Honorable Mention in the second annual AIA Education Honors; Professor Anderson received the MIT graduate teaching award; Professor Imre Halasz and Principal Research Associate Timothy Johnson each were awarded Fulbright grants for travel to Chile in summer 1988.

Professor Habraken has announced his intention to retire from MIT, effective January 1, 1990. The Department will keep him connected to its work by inviting him for lectures, juries and participation in research.

OTHER

The fourth Arthur H. Schein Lecture and Exhibit this year featured the work of William Pedersen ('65). Mr. Pedersen, of Kohn Pedersen Fox, New York, talked on his recent major work, including a fourth and final structure to complete the Rockefeller Center complex in Manhattan, which is currently in the design phase.

The MIT Department of Architecture was well represented among winners of the Boston Visions competition this year, sponsored by the Boston Society of Architects. A submission by the Level III studio group, in the portion of that studio directed by Peter Droege, was awarded a second prize. SMArchS student Bill Boehm and Sebastian Gray ('88) were also second prize winners, as was Paul Lukez (MArch '85). Antonio di Mambro ('71), a former member of the Department's faculty,

won two first prize awards, and Wellington Reiter, appointed to teach design next year, received a first prize as well.

First prize in the 1988 AIAS Fall Design Competition, "Arrivals in Arabia," a new terminal for an international airport in Saudi Arabia, was awarded to Valeria Koukoutsis, a SMArchS student and her partner, an MArch student from the Harvard GSD. Daniel Glenn (SMArchS '89) and his wife Susan Francie Gurney (MArch '90), Paul Ries (MArch '90) were collaborators on a paper awarded first prize in the Open House International 1988 Essay Competition. The work, done last year with Visiting Professor Jorge Andrade, focussed on housing reconstruction efforts following the 1985 earthquake in Mexico City. PhD student Kara Hill was awarded a Fulbright Grant to France for 1989-90; Khaled Asfour, also a PhD student, received an American Research Center in Egypt (ARCE) Award for study in Cairo 1989-90.

Department awards to students: Valeria Koukoutsis and Conrad Margloes were chosen for the SMArchS Award; Carlos Fernandez and Kairos Shen shared the Sidney B. Karofsky Prize as outstanding students entering the final year of study in the MArch program; Donald Knerr and Steven Shortridge were given the Francis Ward Chandler Prize for achievement in architectural design; Julie Chang received the William E. Chamberlain Prize. The Alpha Rho Chi Medal went to Sara H. Haga, for service to the Department and promise of real professional merit. Yuri Kinoshita received the American Institute of Architects (AIA) Certificate, and Mahmood Farqui received the AIA Medal for top ranking student graduating from the MArch program this year.

Department of Urban Studies and Planning

INTRODUCTION

Local, national and international events throughout the year emphasized the importance of our teaching and research. The presidential campaign between Bush and Dukakis highlighted several issues of central concern to planners - the degradation of the environment, the scarcity of affordable housing, competitiveness in international markets and the continuing specter of racial divisiveness. Many alumni and faculty were involved on both sides of the campaign as advisors or protagonists.

The beginning of the school year came as the fall weather cooled the hottest, driest summer in recent memory. The country was appalled and apprehensive about global warming, ozone, garbage barges without a place to land and the closing of beaches due to medical waste. The end of the year was marked by the massacre of pro-democracy students in Tienanmen Square in Beijing, China. The difficulty of making progress in encouraging democratic practices in planning in developing countries was underlined by the events of June 4, 1989. By mutual agreement, the biennial Urban Design Studio taught jointly by MIT and Tsinghua University was postponed. It was to have taken place in June and July.

The department continues its task of consolidating its activities and choosing priorities among its many interests. Over the last year, it affirmed its direction of strengthening its sub-groups by approving faculty searches in Design and Development, Developing Countries and Real Estate Development. It also added lecturers in Environmental Policy and visiting faculty in Housing and Community Development.

EDUCATION PROGRAMS

The PhD Program continues to offer a high quality program that attracts a large number of excellent applicants (74) of whom 15 were admitted. The PhD seminar, conducted by Professors Robert Fogelson and Martin Rein was successful in offering an integrated intellectual experience as an introduction to research in the doctoral program. Five students were awarded their PhD degrees this year.

The Master of City Planning (MCP Program) continues its work in defining the MCP thesis and the Core Curriculum. After a detailed review of theses, thesis preparation seminars and much deliberation over options, the MCP committee adopted (for implementation in 1990-91) a single 24 unit thesis to be done over two terms with a required thesis preparation seminar to be given by each Curriculum Focus Group (CFG). The Core Curriculum continues to evolve with increasing linkage to the CFG introductory courses with the intent of involving the CFG's much more closely in taking responsibility for introducing the practice aspects of their particular group.

The CFG's made considerable progress in planning and offering introductory subjects, subject sequences, thesis preparation courses, advising and ties to the world of practice.

The Community Fellows Program under the direction of Adjunct Professor Melvin King, sponsored ten non-funded Fellows drawn from minority communities across the United States. A proposal for major funding to support youth initiatives was submitted to the Ford Foundation.

The Special Program for Urban and Regional Studies (SPURS) hosted 17 Fellows from the following countries: Phillipines, Brazil, Mexico, Nepal, Honduras, Taiwan, Peru, Bolivia, India and Saudi Arabia. Alan Strout, the present Director, will be retiring from his position. The new director will be Dr. Gillian Hart, who has extensive experience in rural development, especially in Southeast Asia.

EVENTS

The Aumni Association, with the local chapter of the American Planning Association, sponsored a forum featuring the present and first directors of the Boston Redevelopment Authority, Stephen Coyle and Lecturer Edward Logue. Their topic was: "Downtown and the Neighborhoods - a 25 year Perspective." The Student Forum had weekly talks on diverse subjects in community development, developing countries, racism in practice, etc.

FACULTY

Two searches were conducted for junior faculty. The one in Developing Countries resulted in the appointment of Paul Smoke as Assistant Professor. The other in Design and Development will be continued in 1989-90 so that more candidates can be considered.

Visiting faculty were: in Housing and Community Development, Ron Ferguson from the Harvard Kennedy School of Government and Karen Fulbright from the New School for Social Research; in developing Countries, Remy Prud'homme from the University of Paris and Angel Shlomo from the Asian Institute of Technology; in Design and Development, Thomas Piper from the Boston Redevelopment Authority.

Visiting Scholars were Yale Rabin from the University of Virginia, Sam Bass Warner from Boston University, Michael Stone from University of Massachusetts at Boston. The faculty, as usual, were involved in research writing, practice and community service. Some highlights follow:

- Professor Bernard Frieden completed his term as Chair of the Faculty and was appointed as Ford International Professor.
- Professor Gary Hack returned to teaching half-time and continued his professional practice, successfully completing the Master Development Plan for the Prudential Center in Boston. It involved hundreds of meetings and dozens of community organizations and institutions.
- Professor Bennett Harrison spent the fall as exchange faculty at Oxford and the spring at Carnegie-Mellon University, Pittsburgh, PA.
- Adjunct Professor Philip Herr was co-director of the Seoul (Korea) Conference on Hosting the Olympics and worked with former Senator Paul Tsongas in organizing the Model Town Program on Cape Cod.
- Professor Gary Marx wrote extensively on surveillance and police undercover issues in national newspapers and again appeared on Nightline on the subject of private undercover drug agents.

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- Assistant Professor Edwin Melendez was on leave working with the Center for Puerto Rican Studies.
- Professor Karen Polenske travelled several times to China and the Soviet Union to work and lecture on Input-output Accounts and regional planning.
- Associate Professor Bish Sanyal's book Breaking the Boundaries One World View of Planning Education will be forthcoming in the fall.
- Associate Professor Mark Schuster, with Lecturer Dennis Frenchman and visiting Professor Roger Simmons published Housing Design and Regional Character: A Primer for New England Towns. The research was sponsored by the National Endowment for the Arts.

STUDENT AWARDS

Laura Lebow received the AICP Outstanding Student Award; Bonnie Wolf received the Charles Abrams Scholarship. The Flora Crockett Stephenson Award was received by Fay Twersky.

TUNNEY F. LEE

Aga Khan Program for Islamic Architecture

The Aga Khan Program for Islamic Architecture (AKP) established in 1979, functions jointly at MIT and Harvard University to promote research and teaching concerning architecture and urbanism in countries with Islamic societies. Generous gifts from His Highness the Aga Khan support the AKP through endowed funds that provide for faculty, student financial aid, library facilities and research; additional current funding supports publications, documentations, student travel and outreach activities. The role of the central office, located at MIT, is to provide continuous liaison for activities carried out at both universities, to facilitate the coordination of joint, Program-wide activities, to maintain a steady exchange of fiscal and substantive information between the Program and the donor and to coordinate Program outreach in the Third World.

The 1988-89 academic year began the first year of a new three-year fiscal cycle. It was marked by activities both old and new aimed at consolidating, extending, and broadening the work of the Program. Considerable time was spent on improving internal communication between and among students, faculty, staff, the Harvard and MIT communities and the public-at-large. An internal master calendar was circulated to better inform AKP students, faculty and staff of AKP activities, visitors, and staff travel plans; a special newsletter was distributed among students to alert them of program activities and resources, potential jobs, and grant and scholarship opportunities and deadlines. The first issue of a program-wide newsletter was launched to maintain contacts with interested scholars, professionals and institutions at home and abroad and to inform them of our many activities, publications, as well as academic and research programs. A new publications brochure was compiled and distributed as were monthly calendars of our lecture and seminar programs. An international search for two Visiting Aga Khan Professors to be assigned to the University of Jordan in Amman and Dawood College in Karachi was completed as part of the AKP's Parallel Centers program of international outreach. The final prototype of the Videodisc computer system was completed and prepared for installation at the Parallel Centers.

Three new publications made their appearance: *Housing in Tunis* by François Vigier; *A Century of Princes*, a sourcebook on the Timurids selected, introduced and translated by Wheeler Thackston; and the proceedings from our 1987 conference on *Theories and Principles of Design in the Architecture of Islamic Societies*. In addition, volume V of *Muqarnas*, the AKP annual on Islamic art and architecture, was published.

FACULTY

AKP policy is made by an Executive Council currently composed of Professor François Vigier (Chairman, 1988-89), Charles Dyer Norton Professor of Regional Planning at the Graduate School of Design, Harvard University; Oleg Grabar, Aga Khan Professor of Islamic Art and Architecture at Harvard; Professor Ronald B. Lewcock, Professor of Architecture and Aga Khan Professor of Design in Islamic Societies at MIT, and Professor William L. Porter, Leventhal Professor of Architecture and Planning and Head of the Department of Architecture at MIT. Other MIT faculty during 1988-89 included Professor Zeynep Çelik (Visiting Faculty); Mr. Akhtar Badshah, Lecturer/Research Associate in the Design for Islamic Societies unit of the S.M.Arch.S. program, and Mr. Masood Khan, Lecturer who was appointed in September 1988 in the Design in Islamic Societies unit

ACADEMIC PROGRAMS AT MIT

The Design in Islamic Societies component of the S.M.Arch. S. program.

This year, seven new students were enrolled to focus on studies relating to Design in Islamic Societies as part of the Master of Science in Architectural Studies degree program. With seven outgoing students, the unit's strength has thus been maintained at fourteen students. The faculty consists of Professor Ronald Lewcock, Mr. Masood Khan, Mr. Akhtar Badshah, visiting scholars and architects, in addition to the other faculty that the students have access to in the normal course of exposure to the range of subjects offered to the S.M.Arch.S. students both at MIT and Harvard. Student reflection and debate is focused on both practical and theoretical issues in architecture characteristic of non-Western societies: appropriate responses to climate, building materials and building technology together with socio-cultural attitudes and values which have a direct bearing on the relationship of man to his environment. Students are

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encouraged to familiarize themselves with the architectural and institutional forms and structures found in traditional urban environments in the Islamic world and then to compare them with forms and structures which have developed since the spread and application of western ideas in modern times.

In Fall 1988, as in previous years, first year students worked on a series of three workshops using case study material prepared by the faculty. Together, the workshops comprise the studio-workshop course Introduction to Design in Islamic Societies. The first workshop is concerned with familiarizing the students with the forms, functions and institutions of traditional Islamic and other non-western cities. In addition, rehabilitation and the future of old central areas in rapidly expanding cities are dealt with. The workshops introduce students to the problems of clashing ideas in forms and functions, the inter-relationship of the new and the old, the accommodation of modernization (motor traffic, parking, new building types), the provision of housing and other facilities for the urban poor, and to the impinging social and cultural factors of regional and national identity. In 1988 the old city of Ahmedabad was selected. Here differences between the Muslim and Hindu neighborhoods, or *pols*, were studied to understand the above issues and find appropriate means by which the *pols* could be rehabilitated and improved.

The second workshop deals with the *impact* of modern change on these old environments and their architecture, in particular the clash between the old forms and those imported from the western world, or introduced following western ideas. At the same time the workshop focuses on design of public buildings and spaces with appropriate attitudes towards monumentality. In 1988 the case material used pertained to changes brought about in the twentieth century to the old city of Algiers.

In the Algiers workshop, the Casbah and the French intervention along the waterfront were studied, and the students were asked to devise architectural solutions for re-knitting the traditional urban fabric in two specific areas while still accommodating such requirements of modern living as traffic, parking, and over crowding.

The third workshop was intended for the study of various attitudes to infill design related to the earlier two workshops. Because of the limitations of time and resources, the workshops are essentially issue-oriented and can merely point in the direction of possible solutions. Faculty and students worked closely together as a team, although finally certain ideas were explored individually or in small groups.

The Fall 1988 studio-workshop course was also a test model for an unique collaborative venture between the unit at MIT and the College of Architecture and Environmental Design at the University of California at Berkeley. Identical design workshops were offered at both institutions simultaneously, using the same background material and visual documentation. The aim of this parallel teaching experiment was to explore the validity of the DIS teaching approach and introduce the issues related to the urban fabric of the Islamic world to students in Berkeley.

The spring term is devoted to a studio-workshop –Architectural Design in Islamic Societies– which considers a specific architectural design in a rapidly changing traditional environment. The theme of the 1989 DIS studio-workshop was "Designing for Community Health in Old Cairo: Issues of Function, Typology, and the Initiation of Urban Rehabilitation." The project site was the Gamaliya quarter of Cairo, one of the oldest parts of the city, south of the Hakim mosque and the northern city wall, between Bab El Futuh and Bab El Nasr. Dating back to the tenth century, the quarter represents one of the richest repositories of the Islamic tradition of buildings, with examples dating back from the Fatimid, Ayyubid, Mamluk, Ottoman and Mohammed Ali period. The project site has empty pockets of land and recent substandard and temporary buildings which house small industries based on textiles and scrap metal. Cheap labor is provided by the people in the surrounding neighborhoods. Basic facilities are sorely lacking, particularly those relating to community health.

The studio considered appropriate ways to regenerate the district taking the historical urban fabric into account. It focused on the design of a community health facility in an urban context where traditional *bimaristans* - -medieval hospitals – still exist. The requirements of contemporary health care, including housing for staff, was treated in conjunction with the physical and functional relationship that the new buildings will have within the surrounding urban fabric, given its traditional form and building typologies. As the key conceptual framework for the design program, the health center was viewed as a catalyst for urban regeneration of the surrounding district and as a potential example for the urban rehabilitation of medieval Cairo as a whole.

The spring studio included a two-week practical building workshop devoted to traditional building materials and methods still used in Europe, Asia and Africa. Practical work was accompanied by lecture courses and seminars emphasizing the development of design attitudes and methods that can consider indigenous conditions, climate, appropriate building materials and theoretical approaches to creative activity in Islam.

History, Theory and Criticism Program

In the Aga Khan component of the History, Theory and Criticism Program in the Department of Architecture, a search was inaugurated during the academic year to replace Professor Yasser Tabbaa who joined the University of Michigan in the fall of 1988. In the interim, Dr. Zeynep Çelik of Columbia University was appointed as Visiting Assistant Professor to provide continuity in teaching. During the fall she offered a course on "Cross Cultural Development in Architecture and Urbanism in the 19th Century" and during the spring taught "The Architecture of Islam."

Of the six AKP doctoral students in the Program, Khaled Asfour and Kara Hill were in residence in Cambridge, Khaled completing course work and Kara Hill preparing her comprehensive exams and dissertation topic. Both were also successful in receiving dissertation research support for 1989-90, Khaled Asfour from the American Research Center in Egypt and Kara Hill from Fulbright for research in France. Nasser Rabbat continued thesis research in Cambridge during the fall term, then returning to Cairo for the remainder of the academic year to collect additional information on a grant from the American Research Centre in Egypt. Iffet Orbay continued her stay in Turkey through the fall term, completing research for her dissertation and returning to Cambridge in the spring to begin writing and to work as a teaching assistant at Harvard. Richard Brotherton continued work on his dissertation while based in New York. Tulay Artan received her Ph.D. degree with a dissertation topic on "Architecture as a Theater of Life: Profile of the 18th Century Bosphorus" under the direction of Professors Stanford Anderson (MIT) and Oleg Grabar (Harvard).

VISITING SCHOLARS

During 1988-89 the AKP welcomed two Visiting Scholars to the Program, Hugh Andrew O'Neill, Senior Lecturer in the Faculty of Architecture at the University of Melbourne, Australia, and Jo Tonna, a practicing architect and Lecturer in Architecture at the University of Malta. While with the AKP, Mr. O'Neill continued work on the traditional mosque architecture of Indonesia, particularly its vanishing timber tradition. Mr. Tonna completed research and writing on the determinants of architectural form in modern buildings in the Arab World. Both presented a public lecture on their research during their Cambridge stay.

STUDENT SUPPORT

Tuition and living expenses for six doctoral and 15 S.M.Arch.S. students at MIT and one doctoral student at Harvard were funded in whole or in part. Seven students from MIT were awarded summer travel grants for research in Morocco, Turkey, Indonesia and Egypt. An additional four MIT students were awarded travel funds to participate in an internship and study program in Mostar, Yugoslavia.

LIBRARY AND INFORMATION RESOURCES

Specialized acquisitions and services at the Rotch Architecture Library continued to be provided through endowed funds. Under its Information Services and Technology Unit, the AKP's visual documentation center completed a period of testing, evaluation, and reconfiguration of its prototype Images System which integrates database management and graphics with videodisc technology. Early in the project, 3,000 of its 30,000 images had been indexed in depth; during 1988-89 indexing of the remaining 27,000 images was further refined and the prototype prepared for installation and testing at the Parallel Centers in Amman and Karachi.

SEMINARS

Heritage and Change in Southeast Asian Cities - held at the National University of Singapore, August 1988.

An international collaborative workshop on the environmental concerns of Southeast Asian cities has brought together a group of professionals and academics from all parts of the Southeast Asian region, in addition to students from Singapore. It focused on the critical examination and comparative exchange of experiences on the relationship, conflicts and opportunities that exist between the older parts of cities and newer developments.

The two-week workshop was attended by representatives from the People's Republic of China, the Philippines, Malaysia, Indonesia, Singapore and Hong Kong. It took a two-staged approach, first comparing workshop strategies employed by participants in their home countries, and then bringing the energies and solutions of the assembled group together to work on a joint revitalization problem, that of Little India in Singapore. The case-study material was prepared by the faculty and fourth year students at the National University of Singapore.

RONALD B. LEWCOCK and BARBRO M. EK

Center for Advanced Visual Studies

The Center for Advanced Visual Studies, founded in 1967 by Professor György Kepes and directed since 1974 by Professor Otto Piene, has pursued its artistic investigation of individual and group work toward integrated impulse and energies in art-science-technology. Human expression in the environmental arts and performance is its paramount concern in art works and art systems as well as in its academic, educational efforts on graduate and undergraduate levels.

Introductory classes by Otto Piene, Elizabeth Goldring, and Paul Earls, Todd Siler and Joe Davis with presentations by many CAVS Fellows, address students from virtually all MIT courses, e.g. 4.831 Art and The Environment, 4.832 Environmental Art and Performance and 4.838 Special Problems in Environmental Art.

Four SMVisS theses were completed: "Statements by Aroma" by David Larkin; "Tower as Communication" by Gerry McCarty; "Specific Light and Sculpture" by John Powell; "Light Dance: Light and The Nature of Body Movement" by Seth Riskin. Mr. Riskin gave a series of performances representing his thesis work and related performances in 1988 in Karlsruhe, Federal Republic of Germany, and in Savonlinna, Finland, 1989 - most of them in context with CAVS projects.

A major project of the Center, the exhibition Lights/OROT at the Yeshiva University Museum in New York City, closed in June, 1989 after a year-and-a-half run. The exhibition interpreted traditional articles of Jewish faith with contemporary media such as laser, holography, computers, video, inflatables, optics. It has filled the museum's visitors calendar to capacity throughout its duration.

In July 1988 the Visual Arts Center of Alaska in Anchorage, AK, again produced with CAVS "Sky Art Alaska", a series of sky events and installations in Anchorage where Otto Piene, Elizabeth Goldring and Christopher Janney created Sky Cry, a multimedia sky performance. The Deutscher Künstlerbund of the Federal Republic of Germany invited CAVS artists to mount an exhibition with performances, Otto Piene und das CAVS as part of the anniversary exhibitions of the Künstlerbund, in Karlsruhe, Germany. Ca. 45 Fellows and former Fellows participated in the resulting first major Center retrospective, Sept./October 1988. The exhibition was accompanied by a substantial catalog edited by Fellows Bill Seaman and Ellen Sebring.

A CAVS group participated with individual works and a new Monocle installation of this CAVS group work at Celebration of Light in Savonlinna, Finland, 1989. A major interactive Monocle installation had been shown previously at Images du Futur in Montreal, Canada, 1988. In June '89 another Images du Futur exhibition celebrating the Bicentennial of the French revolution included Kikeriki, an environmental, programmed sculpture by Otto Piene, Elizabeth Goldring and Christopher Janney, with Lees Ruoff.

Design Expo '89 and corporate sponsors in Nagoya, Japan, created ARTEC '89, the first international biennale for works of art and technology. Among

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the 26 participants were 6 former CAVS Fellows (Catherine Ikam, Setsuko Ishii, Piotr Kowalski, Bill Parker, Alejandro and Moira Sina; Otto Piene, advisor.)

Since 1987 CAVS has developed an environmental multimedia park for Kendall Square, Cambridge, "Galaxy", with the Cambridge Redevelopment Authority, Monacelli Associates, architects, and Halvorson Associates, landscape architects. Stage 1 including a water/steam fountain with a welded earth sphere and 12 surrounding "Moon Lights" is presently being installed. Principal designer: Otto Piene; artists: Joan Brigham/Joe Davis.

Long-time CAVS Fellow Lowry Burgess spent years of collaboration with NASA on placing his sky art work, part of his "Quiet Axis" system series, on a shuttle flight. In March '89 it was carried by the Discovery as the first "non-scientific payload". Upon its return it has been determined to be placed in a rock near Walden Pond by the DeCordova Museum in Lincoln, Mass.

Other individual projects: Elizabeth Goldring and Vin Grabill completed a videotape on eyesight deterioration - "The Inner Eye" - sponsored by the Diabetes Foundation. Paul Earls participated with former Fellows Wen-Ying Tsai and Milton Komisar in an IBM exhibition in New York City, Computer as Art. His installation, Modulations II, was also shown in Karlsruhe and Hannover, Federal Republic of Germany, in 1988/89. He was commissioned to contribute a laser-music piece to "La Jour de Bastille 200" at the French Library in Boston.

Both CAVS founding director György Kepes and Director Otto Piene had various international one-man exhibitions. Several exhibitions in Germany celebrated the role of the Hungarian avant-garde in 20th century art (Kepes). Piene was part of the Berlinische Galerie historical exhibition, Stationen der Moderne, with a reconstruction of the 1963 Berlin Zero manifestation (Mack-Piene-Uecker).

Ellen Sebring, with former Fellow Beth Galston, presented Aviary a multimedia dance and video performance at the Media Lab "Cube" in the spring of 1989. With support through grants from the MIT Council for the Arts, works and performances by Fellows and grad students became possible at CAVS and other MIT locations by Joe Davis, David Larkin, Jerry McCarty, Atsushi Ogata, John Powell, Seth Riskin, Ellen Sebring.

Fellows received grants from Fujitsu Foundation (Ogata), Gulbenkian Foundation, Luso-American Foundation (Clara Meneres, Jose Nuno) and the Danish Government (Thorbjörn Lausten). Major Massachusetts Artists Foundation Fellowships were awarded to Bill Seaman and Ellen Sebring. Dieter Jung's work was honored with the first grand prize in holography from the Museum of Holography in New York City.

Lowry Burgess has been appointed Dean of the College of Fine Arts at Carnegie-Mellon University in Pittsburgh, PA.

OTTO PIENE

Center for Real Estate Development

This year marks the conclusion of the first five years of the graduate program in real estate development. When the MIT Faculty voted in 1984 to approve the Master of Real Estate Development (MSRED) program, it required a five year review by the Committee on Graduate School Policy (CGSP). To facilitate the review the program's Senior Faculty Advisory Committee, chaired by Dean John de Monchaux, undertook its own extensive self-study. CGSP established a Subcommittee to Review the Real Estate Development Program; its recommendation, accepted by CGSP and approved by the MIT Faculty, was as follows:

Faculty recommend to the Corporation continuation of the Master's Degree Program in Real Estate Development for a period of five years and that CGSP continue to review and evaluate the program.

This review was guided by four broad questions posed by Dean Frank Perkins:

1. Has the program been successful in attracting a cohort of high quality students and in providing them with an educational program which is academically excellent and responsive to their needs?
2. What progress has been made in developing a deeper understanding of the real estate development process and in incorporating that understanding into the academic program?
3. To what extent does the program provide an important and recognized service to various segments of the real estate development industry?
4. How is the program actually structured, staffed, housed, and administered, and are these arrangements such that the program's intellectual development and administrative stability can be reasonably assured?

This report provides an opportunity to review the first five years and summarize some of the responses to these questions. The MSRED program was the first in the country to offer a graduate degree in real estate development. Columbia, UCLA, the University of Southern California, New York University, and a half dozen other universities quickly followed suit. Most of these schools have adopted a similar course sequence and the 12-month format created at MIT. Two European universities, the University of Amsterdam in Holland and the University of Turin in Italy, have also adopted this model.

The strength of the program is revealed by its success in enrolling accepted students. The yield ratio (acceptance letters versus those who actually enroll) has ranged from 85 to 95 percent. Of the 180 people accepted in the first five years, only two have chosen to go to competing real estate programs. The admission pool has fluctuated from 120 to 180 applicants for a yearly class size of 35. The median age of students is 31 years and approximately 30 percent are female. Unfortunately, minority enrollment has not exceeded 10 percent in spite of targeted recruitment efforts and special financial aid. (We have high hopes that our Minority Development Executive Program, however, will help attract more minority candidates to the graduate program.) In the four classes that have graduated to date, only one student has withdrawn; one other failed to complete the thesis on time, but was subsequently graduated.

The graduate program is housed at the Center for Real Estate Development and is an integral part of the activities of the Center. The degree program is funded from a portion of tuition revenues (39 percent), contributions from other departments (7 percent), and the Center's general resources (54 percent).

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The Center is financially self-supporting. More than 80 firms pay \$5,000 or \$10,000 annually (depending upon size) for Center membership. In its first five years the Center has raised \$6.65 million of direct support, of which \$2.7 million has been raised through annual membership fees. The room designation program has raised \$754,000 to renovate space for offices, classrooms, and support facilities for the Center and the degree program.

The strength of the alumni commitment to the Center over these first five years has been exemplary. One third of the alumni to date (47 out of 140 graduates) have pledged or given \$1,000 or more to the Center, a remarkable statistic.

Since its inception, the Center has raised approximately \$1.2 million for research. Roughly 40 percent of these funds have come from membership fees with the balance coming from funded research. The bulk of this money has been used for faculty support. The Center has funded four doctoral dissertations to date, as well as supporting a number of doctoral students who have yet to start their dissertations.

The Center has established itself as an important research resource in a number of fields. Three faculty members (Wheaton, Birch, and DiPasquale) have been exploring the structural characteristics of real estate markets as well as the demand for space. The Center has been a sponsor of work on public-private partnerships (Frieden and Sagalyn), the impact of foreign investment on U.S. real estate markets (Bacow), the correlation of real estate performance with the economy (Sagalyn and Louargand), affordable housing (McKellar), and negotiated development (Wheeler and Lambert). Working papers on these topics have been widely disseminated. The Center has also assisted in the preparation and release of 20 papers on housing policy, edited by Professors Keyes and DiPasquale, that will soon be released in book form.

In the year ahead the Center will have a major role in housing research in conjunction with the Department of Architecture and will launch a new project to assess the value of good design. Professor Bacow will be on a one-year leave from the Center to undertake research that will provide a better understanding of the entire development process.

The results of the Center's research highlighted the June 1989 members' meeting, "Real Estate and the Business Cycle, Home and Abroad." Presentations by four faculty members (Bacow, Louargand, Sagalyn, Wheaton), who teach in the graduate program, were a fitting culmination of the Center's first five years. Publication of this research was made possible through a working paper series funded by Citicorp Real Estate, Inc.

The Center is now strengthening its faculty structure. The School of Architecture and Planning has committed two tenured faculty appointments, one in Architecture and one in Urban Studies and Planning, each of which will carry significant teaching and research responsibilities in the Center. The Center has also clarified its organizational structure, including a more significant role for the Senior Faculty Advisory Committee. While the Center has created a new position, director of placement, the total staff and overhead of the Center have been reduced. These changes are seen as essential to the intellectual and financial health of the Center over the next five years.

The MIT Center for Real Estate Development is an alliance of industry, government, and academia created to improve the theory, education, and practice of real estate development. The five year review has confirmed the continued willingness of the Institute, through the next five years, to foster this task.

JAMES MCKELLAR

Laboratory of Architecture and Planning

The School of Architecture and Planning's research maintained a stable volume over the past year. Projects continued to focus on a variety of issues, covering a range of concerns to the fields of architecture, city planning and real estate development. As in recent years, the Laboratory of Architecture and Planning (LAP) served as the administrative base for all of the sponsored research and many of the educational workshops conducted by the many special interest programs of the School. Among the programs are: The Center for Real Estate Development (CRED), the East Asian Architecture and Planning Program (EAP), the Building Technology Group, the Aga Khan Program for Islamic Architecture (AKP), the Computer Resource Laboratory, and the Program for Job Generation.

During the year a subcommittee of the School Council completed a wide ranging review of research development and management within the School. These deliberations led to a plan for reorganization in the School to be implemented in AY 89-90. Management of research and special program accounts will be decentralized to the Department of Architecture and the Department of Urban Studies and Planning. Research development, on a Schoolwide basis, will focus on housing research; this will involve the deployment of professional personnel and seed funds available for Schoolwide use. The focus on housing research is meant to establish the School as a national leader in the field by harnessing all related resources within the School in collaboration with colleagues throughout the Institute. The new, major housing research program will be developed in close cooperation with industry and professional associations. Developmental support for other topics of research will be provided by the Departments and special program groups. LAP research and administrative personnel will be based in the Departments or in the Office of the Dean.

CURRENT RESEARCH

Professor James Axley, with support from the National Bureau of Standards, continued his research model of interior air pollution, work begun at the Bureau prior to his joining MIT.

Professor Lawrence Bacow and researcher Marc Louargand completed a study of the performance of real estate in a recessionary environment, sponsored by Citicorp Real Estate, Inc.

Professor Bacow continued his research about foreign investment in the US real estate market, with support from the National Association of Realtors.

Professor Ranko Bon began a project, sponsored by the US Civil Engineering Research Laboratory, to investigate the decision criteria about real property used by Army base commanders to meet their command objectives.

Professor Phillip Clay continued research sponsored by a grant from the Ford Foundation to develop case studies about the community housing sector. The research primarily addresses the question of what the barriers are to a more effective role in housing development on the part of the community-based sector.

Associate Dean Lois Craig completed her project to develop a visual video disc collection describing the Boston suburbs supported by the National Endowment for the Arts.

Professor Leon Glicksman and Professor Lorna Gibson, with Research Associate John Crowley, continued their project to evaluate how composite materials can be incorporated into new building systems for housing construction. Their work is supported by a consortium of the nation's major building materials manufacturers and advised by a panel of home builders. A second consortium-supported project began this year to explore manufacturing techniques and management for new building systems.

Professor Glicksman completed his work to measure the permeability of air components of several foam samples produced by Mobay Chemical Company. The goal of the project was to relate aging to different polymer systems to be used in foam insulation.

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Professor Les Norford accepted the responsibility of developing the lighting and building technology laboratory supported by GTE Sylvania.

Professor Donald Schon continued work on his Ford Foundation project to document the "best practice" in social investment and to provide the Foundation's personnel with a framework to inform their daily work.

Professor Lawrence Susskind, sponsored by the US Department of Labor, continued his research about collective bargaining and principled negotiation.

The Grunsfeld Research Incentive Awards continue to provide a very important source of funding for small-scale, exploratory research by students and faculty of the Department of Architecture.

SPECIAL EDUCATION PROGRAMS AND PUBLICATIONS

The LAP, in collaboration with MIT's Office of Facilities Management Systems, conducted a three week management institute in Cambridge for Japanese facilities managers. Presented in cooperation with the Japan Facilities Management Association, the institute will be run for three consecutive years. Japanese corporations provide support for the development of curriculum material. Michael Joroff and Kreon Cyros were co-directors, Visiting Professor Patrice Derrington served as associate director.

The Seoul Studio, a summer program of the MIT East Asian Architecture and Planning Program, brought together students from North America and Korea to explore issues of low-rise, high density housing design in Korea's capital city. Professor John Myer was the senior MIT instructor who worked with colleagues of Seoul National University.

The Kawasaki Advanced Information City Workshop explored the concepts, development strategies and design of cities as they emerge in the 21st century. Students and practitioners from nine countries were brought together in the urban city of Kawasaki and the rural town of Ogaki by the MIT East Asian Architecture and Planning Program. Michael Joroff and Peter Droege directed the effort for MIT in cooperation with faculty colleagues of the Tokyo Institute of Technology.

Biennial Shelter Workshop 1988 was a two week workshop presented by experts in community-based planning. Presented by the Professional Practice Program, the workshop attracted participants from developing countries on five continents. Professor Nabeel Hamdi and architectural lecturer Reinhard Goethert directed the program.

Professor Ranko Bon and Michael Joroff directed a team which presented the major plenary session at the 1989 conference of the National Association of Corporate Real Estate Executives. The session focused on the criteria for corporate real estate management effectiveness, as determined by a 1988 LAP survey of Fortune 500 firms.

The LAP continues as one of the sponsors of "Open House International", a journal of housing, co-edited by Professor Nabeel Hamdi of MIT's Department of Architecture.

STAFF

During academic year '89 the LAP hosted two new Visiting Research Scholars. Professor Yasuyuki Takaguchi, a Professor at Nara Women's University in Nara, Japan; and Mr. Guang-Jeng Lai, Senior Specialist in the Department of Urban and Housing Development, Council for Economic Planning and Development, Taipei, Taiwan.

Michael L. Joroff

Media Arts and Sciences Section

In its second year of operation, the Media Arts and Sciences Section continued to bring together the various teaching efforts associated with its multi-disciplinary charter, widen its faculty recruiting efforts, and evolve the infrastructure supporting its expanding graduate program.

EDUCATION:

Access to the educational resources of the Section will improve for all MIT students as a result of a major reorganization of our listings in the yearly Bulletin. Fifty-four subjects were offered by the Section this year.

Graduate:

One hundred forty-five applications for our graduate program were received, from which 25 were selected for admission. Our graduate student population this year consisted of 64 students (40 MS, 24 PhD, 8 women, 2 under-represented minorities). Twenty-one advanced degrees were awarded during the year (19 MS, 2 PhD).

Undergraduate:

The number of undergraduate subjects offered increased to 13. While the Section has no official undergraduate academic program, the 110 UROP students active in the Media Laboratory maintain our lively interaction with the undergraduate student body. Of these, many do their undergraduate thesis research under our faculty's supervision. Four subjects were offered during IAP, involving seven faculty members.

FACULTY AND STAFF:

Promotions:

Professor Tod Machover was promoted to Associate Professor.

Professor David Zeltzer was promoted to Associate Professor.

New Appointments:

Professor Marvin L. Minsky was appointed Toshiba Professor of Media Arts and Sciences.

Professor Seymour A. Papert was appointed Lego Professor of Learning Research

Dr. J. L. Bernd Girod was appointed Assistant Professor of Media Technology in January 1989. Dr. Girod received the Dr.-Ing. (E.E.) degree from the Universität Hannover, Germany, in 1987. His interests include multi-dimensional signal processing, image encoding, and advanced television systems.

Dr. V. Michael Bove was appointed Assistant Professor of Media Technology effective July 1989. Dr. Bove received his Ph.D. in Media Arts & Sciences from MIT in June of 1989. His interests include television technology, machine vision, and digital image processing.

Retirements:

Professor Richard Leacock, Director of the Film/Video Group, retired in February 1989. Professor Leacock has moved to Paris, where he is working on new and experimental ways of making observational films.

Honors & Awards to Faculty Affiliated With the Media Arts & Sciences Section:

Professor Bernd Girod received the Best Paper Award for 1988 from the German Information Technology Society.

Professor Marvin Minsky was named MIT's Killian lecturer for '89-'90.

STEPHEN A. BENTON

Media Laboratory

INTRODUCTION

The Media Laboratory (Media Lab) concludes its sixth year of operation and its fourth year in the Wiesner Building with this report. The year marks a significant (30%) increase in research volume to \$7.1 million and an increase in its research community at the faculty, research staff and research assistant levels. Funds expended in support of Media Laboratory research and Media Arts and Sciences academic programs were significant as well, exceeding \$1.4 million.

The year was marked by a number of new developments in intellectual property rights, sponsorship, sponsor relations, hardware enhancement and research.

In the area of intellectual property, a formal policy was developed by the Laboratory, approved by the Institute and now implemented, whereby all Laboratory Sponsors share in the rights to all intellectual property developed at the Laboratory. This has been achieved by the creation of a Consortium of Sponsors, in which each sponsor of the Laboratory is a member of the Sponsor Consortium and entitled to certain rights to intellectual property generated by the Laboratory, based on the scale and nature of their support. The current sponsor list (appended at the end of this section) includes all those institutions qualifying as Sponsors of the Laboratory under the terms of that arrangement during this past fiscal year.

New endowment received this past year included; two full professorships, one funded by Interlego A/S for the LEGO Professor of Learning Research awarded to Professor Seymour A. Papert and another funded by Toshiba Corporation for the Toshiba Professor of Media Arts and Sciences awarded to Professor Marvin L. Minsky; and one career development professorship supported by Asahi Broadcasting Corporation for the Asahi Broadcasting Corporation Career Development Professor of Media Arts and Sciences, expected to be awarded to Professor Glorianna Davenport in December of 1989.

New sponsors of directed research, during the year, include AT&T, General Instrument Corporation, Hewlett-Packard Company, NEC Home Electronics, Ltd. and Sun Microsystems, Inc.

The Laboratory's discretionary research sponsors were formalized during the year as the Media Technology Group with its distinct rights and privileges. New members in this category include: Electronics Data Systems/CMI, Lotus Development Corporation, McCann-Erickson Worldwide, and Pioneer Electronic Corporation.

The past year saw a major enhancement of the Laboratory's computer processing capabilities, with major equipment gifts from Apple Computer Incorporated, Digital Equipment Corporation, Sun Micro Systems, Inc. and New England Digital Corporation.

The Laboratory's parallel processing capability was substantially increased by the acquisition of a CM2 connection machine to replace its CM1 with generous support from NYNEX and significant research support from Thinking Machines, Inc.

The broadening base of sponsor support in the public sector is reflected in the continuing grant support by the National Science Foundation and a major new program sponsored by the Defense Advanced Research Project Agency (DARPA). These projects complement the Laboratory's main support from corporate sources in the USA, Japan and Europe.

The Media Laboratory continues to increase its dissemination efforts with an expanding program of forums, colloquia, seminars, workshops and meetings with sponsors and with peer groups. In the latter category, there was an intensive NSF workshop organized by Professor David Zeltzer on the Mechanics, Control and Animation of Articulated Figures with sixty participants in April. The workshop results will be published by Morgan Kaufman Publishers as "Making Them Move: Mechanics, Control & Animation of Articulated Figures." The Learning Research Group ended the year with a month-long Summer Session Workshop for over sixty teachers under its NSF Teacher Training grant.

The Laboratory also initiated this past year a series of large scale symposia to mark major occasions during the course of the year, including the award of the LEGO chair in February, the \$1.6M equipment gift from Digital Equipment Corporation in March and "Entertainment in the Next Millennium" in June to mark the third anniversary of the "Movies of the Future" program.

The Media Laboratory's Villiers Experimental Media Facility housed a series of concerts and multimedia events during the year. The highlight was the USA premier of Professor Tod Machover's opera VALIS in June, following its world premier in Paris in 1987.

"Beat Dedication", a computer animation movie produced in the Media Lab's Visible Language Workshop by Bob Sabiston, won awards in many national and international expositions including New York, Los Angeles, Paris, Tokyo and Brussels.

The research team in the Media Laboratory has increased to 40 faculty and staff, 64 Media Arts and Sciences graduate students (40 master candidates and 24 doctoral candidates) who all received full time research assistantships and 23 Media Lab supported M.S. and Ph.D. research assistants from other departments and schools including Electrical Engineering and Computer Science, Political Science, Mechanical Engineering, Physics, Mathematics, Health Sciences and Technology and the Technology and Policy Program. The UROP (Undergraduate Research Opportunities Program) in the Media Laboratory now supports 110 undergraduates.

This year was the second full year of implementation of the Media Lab's \$10 million accord with Nihon University to collaborate in the planning of a new research institute in Japan, the International Advanced Research & Development Institute (IARDI). Lecturer Tomoyuki Sugiyama is continuing with us into his second year. He has been joined by Hiroshi Yoshikawa and Hiroshi Koyanagi. The three man team is actively developing a policy and a research program for the new enterprise. Issues now being progressed include the identification of research projects, the development of a sponsoring environment to support the research program and finally, the investigation of appropriate management procedures for the new institute. In each of these areas, the experience of the Media Laboratory is being drawn on where appropriate.

PERSONNEL

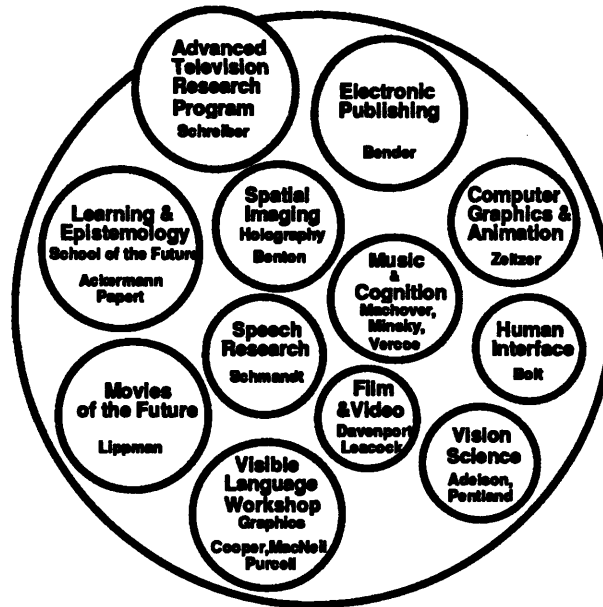
Professor Nicholas P. Negroponte continued as Founding Director of the Media Laboratory with an ongoing focus on strengthening the sponsorship, research programs and staffing of the Laboratory. Andrew B. Lippman, as Associate Director of the Laboratory, leads the "Movies of the Future Program" in addition to coordinating all of the Laboratory's central computing facilities. Robert P. Greene was promoted from Assistant Director to Associate Director for Administration and Finance of the Laboratory, effective January 1, 1989 in recognition of his broader administrative responsibilities.

Dr. Richard A. Bolt was promoted from Principal Research Scientist to Senior Research Scientist. His new appointment becomes effective July 1, 1989. William F. Kelley, formerly Technical Instructor at the Laboratory, took on additional responsibilities in January 1989, when he was transferred to the Sponsored Research Staff and was named Director of Technical Services for the Laboratory. Ms. Julie L. Walker transferred from the Media Laboratory research staff to the Media Arts and Sciences Section staff as Technical Instructor on July 1, 1988 to more accurately reflect her teaching responsibilities.

Staff departures from the Laboratory during the year include Ms. Julie I. Rohwein, Systems Programmer, who left in June to complete her thesis and Henry Holtzman who left his position as System Programmer in February to pursue graduate studies.

New additions to the research staff during the year included Mark Sausville as Systems Administrator in May and Michael Bove, Ms. Idit Harel, Ms. Paula Hooper, and Saqib A. Khan as Research Associates. Michael Schrage joined the staff in September 1988, on a one-year appointment, as a Research Affiliate to edit and oversee production of some of the Media Laboratory's reports and publications.

CURRENT RESEARCH



I. SIGNAL PROCESSING

1. Multi-sensor Systems for 3-D Scene Analysis
2. Model-Based Television
3. Early Vision
4. Pyramid Image Coding
5. Cooperative Perception of Shading & Reflectance
6. Micro-Movies
7. Paperback Movies
8. Depth From Focus
9. Desktop Movies

7. Computers and Telephony
8. Desktop Audio
9. Back Seat Driver
10. Synthesis of Affect: Attitudes to Conversation
11. Voice Windows
12. Network Based Voice Services

II. MEDIA TECHNOLOGIES

1. Advanced Television Research Program
2. Audience Reactions to High Resolution Television
3. Ad Hoc Policy Group on HDTV
4. Interactivity
5. Media Modalities
6. The Future of the Mass Audience
7. Self-Disclosing Television
8. Unrecordable Video
9. Adaptive Color Coding
10. Hard News
11. Personalized Newspaper
12. Spread Spectrum Technology
13. Wide-Angle Synthetic Holograms
14. Edge-Lit Holograms
15. Holographic Color Control
16. Electronic Holography

IV. APPLICATIONS OF MEDIA TECHNOLOGY

1. Society of Mind
2. Animal Construction Kits
3. Meta-Media, a Multi-Media Authoring Testbed
4. Topographical Typography / Dynamic and Intelligent Graphics in Mapping
5. Tone of Voice Typography
6. Design Constraint System
7. Graphics for Software Visualization
8. Intelligent Assistants for Visual Problem Solving
9. Visual Information System
10. Interactive Cinematics
11. Elastic Movies
12. Advanced Interactive Mapping Displays
13. Hyperinstruments
14. Parallel Computation of 2-D Fourier Transforms
15. Synthetic Holography for Computer-Aided Design
16. Holograms for Medical Imaging
17. The Synthetic Performer
18. Synthetic Listeners
19. The Artificial Acoustic Ambience
20. Looking At People
21. Exploratory Design and Visualization: Virtual Manufacturing
22. Constructionism: A New Opportunity for Elementary Science Education
23. Using Computers to Combat Illiteracy
24. Children as Cyberneticists
25. LEGO/Logo

III. HUMAN INTERFACE

1. Eyes As Output: Eyes in Multi-Modal Computer Dialogue
2. Knowledge Based Animation
3. Data Glove
4. Tactile Simulation/Force Feedback Joystick
5. NSF-Sponsored Animation Workshop
6. Font Scaling

The balance of this year's statement consists of reports from projects. These fall into four distinct categories as follows: SIGNAL PROCESSING, MEDIA TECHNOLOGY, HUMAN INTERFACE, and APPLICATIONS OF MEDIA TECHNOLOGY. The HUMAN INTERFACE listing provides evidence of the role media technology to mediate between the user & the user's information environment. SIGNAL PROCESSING evidences a methodological infrastructure to many of the projects in the Media Laboratory. MEDIA TECHNOLOGY and APPLICATIONS OF MEDIA TECHNOLOGY show the very broad spectrum of human affairs touched by this new interdisciplinary field.

SIGNAL PROCESSING

Modern signal processing points in the direction of channel understanding of information content and use of such knowledge to facilitate transmission. The following nine projects are drawn from cinematic, television and telecommunication applications. The immediate achievements are representations (video, videographic, holographic, and photographic); the longer-term consequence is computer recognition and understanding.

Multi-sensor Systems for 3-D Scene Analysis (Professor Bernd Girod)

Development of sensor systems and signal processing algorithms for the recovery of the three dimensional structure of time-varying scenes. The scope of the research includes active and passive range sensing techniques as well as integration of various depth and orientation cues into a 3-D model that can interface directly with computer animation algorithms and model-based television.

Model-Based Television (Professor Bernd Girod)

Unlike today's waveform-based TV systems, model-based TV represents moving 3-D scenes rather than moving images, which are 2-D projections of these scenes. This project develops compact scene representations that are suitable both for data compression and for interactivity. The coder contains a vision system while the decoder is based on computer animation techniques. Research aims at applications such as ultra-low bit-rate coding of moving video for storage and transmission, computer-aided post-production of motion pictures, 3-space data bases, holographic TV, and virtual realities.

Early Vision (Professor Adelson)

We are developing early vision mechanisms that emulate the processing that occurs in primate visual cortex, and are designing algorithms that apply them with high computational efficiency. The mechanisms are useful for edge detection, texture analysis, and image enhancement.

Pyramid Image Coding (Professor Adelson)

Pyramids are multi-scale transforms that are useful in image analysis and image coding. We have previously developed pyramids using quadrature mirror filters, which give excellent image data compression. We are now developing a variant on this type of pyramid using hexagonal sampling; it leads to a transform that captures information about orientation and scale, and allows for improved data compression with very good image quality. Another useful class of pyramids is based on "steerable filters;" these will be useful in machine vision applications.

Cooperative Perception of Shading and Reflectance (Professor Adelson and Professor Pentland)

One of the fundamental problems of perception is that a given pattern in a two-dimensional image can arise from many configurations in the three-dimensional world. For instance, a light-dark edge may arise from a change in surface color, surface orientation, or illumination. We are devising a cooperative model that can disambiguate these various sources for simple scenes. The model consists of a set of specialized mechanisms, each with expert knowledge about its own domain (e.g. shape, or shading, or reflectance); these mechanisms work together to find the best interpretation of the image.

Micro-Movies (Walter R. Bender/Andrew B. Lippman)

Micro-movies are extremely small moving images that use time rather than size as an explanatory dimension. Complete screens of typical window systems are populated with multiple small moving images that can each become animated as they are signalled by either the user or a program. A sample application involving a synthetic "Yellow Pages" is under development in which each advertisement has a micro movie associated with it.

Paperback Movies (Andrew B. Lippman)

A three-year, multi-sponsored venture to research future technologies for the production and distribution of movies (sequential image sequences, with sound). A cornerstone of the program is computer understanding of visual sequences and their digital representation. Other components include computer graphic rendering and manipulation of sequences, three-dimensional data bases for moving image sequences, and research on sound techniques. The Paperback Movie Program is an ongoing effort to encode movies for extremely low bandwidth channels or small scale storage media such as optical discs. A longer range goal is transmission of movies through telephone lines. The main features of the work are: (1) asymmetric encoding, where the encoding is more complex than the decoding, which is inexpensive and realtime; and (2) vector quantization as an analysis and encoding technique.

Depth From Focus (Andrew B. Lippman/Professor Alex Pentland)

A "Range Camera" is under development that will capture the intensity and distance of all objects in front of it. This camera is being designed for real-world, moving sequences. Programs are under development to derive depth from focus and to use the range information to build an intelligent three-dimensional model of the scene that can be rendered from a perspective view other than that from which it was originally taken.

An associated project is currently developing a real-time version of a new type of range camera that has, in off-line experiments, proven to be nearly as accurate as commercially available laser rangefinders. The technique is based on the idea of measuring DE-focus in the image, as opposed to measuring focus as is done in cameras, etc. The advantages of this technique are: (1) it is passive, and thus (unlike laser rangefinders) both eye-safe and undetectable; (2) it has no "shadowed" areas where range information is not available, unlike lightstripe methods or stereo; and (3) it uses only simple, parallel operations, so that a real-time version can be built using only inexpensive commercial image processing equipment.

Desktop Movies (Andrew B. Lippman)

Work is beginning on systems to determine the feature set needed for digital movies in workstation environments. One project under way involves creating movies automatically from an ensemble of archetypical images including actors and backgrounds under the control of a computer process rather than a fixed script. The general theme is the incorporation of independent activity at the interface, and the technical underpinnings include exploration of the representation of the images necessary for interactive assembly and image alteration. The data is stored using the same format as is used in Paperback Movies (above), but the emphasis is on interaction within the frame and alteration of sequence instead of continuous playback.

MEDIA TECHNOLOGIES

Media Technology is an interdisciplinary venue where new forms of information technology, hitherto researched and taught as isolated disciplines, find innovative applications in a broad spectrum of human affairs. The role of this multifaceted subject in projects which link audio, video and all the modalities of input/output are illustrated in the following projects.

Advanced Television Research Program (Dr. William Schreiber)

The Advanced Television Research Program is funded by the members of the Center for Advanced Television Studies, a group of companies broadly representative of the TV broadcasting industry. (If the members are to be listed, they are ABC, Ampex, Kodak, NBC, PBS, Tektronix, Time, Inc. (Home Box Office), and Zenith.) The function of the program is to find ways to design improved TV systems, to encourage students to enter the TV industry, and to provide a place for sponsors to discuss matters of common interest without violating the antitrust laws. The work is carried out in the Media Laboratory and the Research Laboratory of Electronics.

Our audience research has indicated that the main limit to picture quality in typical homes is set by transmission impairments in the over-the-air channel. We have found that it is possible to overcome the main impairments (e.g. ghosts, noise, and interference) by using an entirely new design concept in which the signal transmitted has the character of random noise. The signal is decoded in a smart receiver to produce a conventional video signal for display. By this means it is possible not only to increase the robustness of the signal, but at the same time to provide much higher picture and sound quality within a given bandwidth. Higher spectrum efficiency is also achieved so that more stations can be accommodated within a given overall spectrum allocation. Versions of the same technique have been devised for cable, satellite broadcasting, and optical fiber. A system based on these principles has been submitted for consideration by the Federal Communications System as the new US high-definition standard.

Entirely new systems of this nature cannot be accepted by today's receivers and thus require simultaneously transmitting the same program in the old and new formats, in separate channels, during a transition period (our MIT-CC Project). Many broadcasters object to this and prefer a compatible signal format. We have therefore also demonstrated a compatible version of the new system (MIT-RC Project), which provides improved picture quality within one of today's channels but which does not have the improved resistance to channel impairments or the higher spectrum efficiency. The same smart receiver is used in the compatible system, which is intended to be phased out after a transition period. .

Audience Reactions to High Resolution Television (Dr. W. Russell Neuman)

Systematic experimental research on the responses of typical viewers to HDTV in a simulated home-viewing environment conducted at the Lab's Audience Research Facility over the past two years has already had a significant impact on industry strategy and federal policy in this new field. The original model for technical development of HDTV was a "shotgun" approach of packing extra picture elements in each scan line and doubling the number of lines per frame. Dramatic experimental results demonstrating an interaction effect between the subjective evaluation of picture resolution and viewing distance, screen size, screen shape, programming content and viewer expectations revealed the need for a more sophisticated and extensible approach to high resolution imaging systems.

Ad Hoc Policy Group on HDTV (Dr. W. Russell Neuman, Richard J. Solomon, Dr. Lee McKnight)

At the request of Congressmen George E. Brown, Jr. and Edward J. Markey and in cooperation with DARPA, NSF and the Congressional Research Service, the policy research contingent of the Laboratory has been conducting an ongoing series of workshops and seminars in Cambridge and Washington on HDTV as an issue of scientific and industrial policy. A central theme of these cooperative industry-academic-government fora has been the need to define HDTV as more than a minor extension of analog broadcasting technology, but rather as a major milestone in the integration of high-speed digital computation, intelligent systems and graphic imaging. Media Lab staff are also actively participating the FCC Advisory Committee research on advanced television systems and the Advanced Television Test Center.

Interactivity (Dr. W. Russell Neuman)

Early field tests of videotex information systems and interactive video technologies in contexts outside of the workplace have produced surprisingly disappointing results and evidence of strong user resistance. The Audience Research Facility has conducted a series of studies on electronic home shopping, interactive advertising and interactive television news in a systematic assessment of how "user-active" technologies can be optimized for the informal, information-browsing psychology of the home. Early results indicate that option of interrupting ongoing video is highly valued but that step-wise, information-retrieval menu systems are ill-suited to the home environment.

Media Modalities (Dr. W. Russell Neuman)

Marshall McLuhan had posited some time ago that the nature of the communications medium may have as much effect on the audience member as the message content itself. Surprisingly, little systematic research has been conducted to explore what lies behind his provocative pronouncement. In cooperation with Professor Ann Crigler at the University of Southern California and Professor Marion Just at Wellesley College, the Audience Research Group has been testing differential learning and attitude change among adults randomly assigned to text, audio and video conditions. Early results indicate that the most important factor is the differential formatting of information in the various media, not the physical attributes of communications modalities. A book manuscript based on the project is nearing completion.

The Future of the Mass Audience (Dr. W. Russell Neuman)

Work will be completed this fall on The Future of the Mass Audience to be published next year by Harvard University Press. The study assesses the dynamic tension between the individualizing capacity of intelligent communications media and the constraining pressures of mass-audience economics.

Self-Disclosing Television (Walter R. Bender/ Andrew B. Lippman)

This project incorporates computing into the television receiver that interprets the content of programs by sound and image analysis by decoding the closed caption information that is packaged with the programs. The goal of this project is to ultimately construct systems that quite literally synthesize programs unique to each viewer. Initial work is in place that augments the broadcast with material drawn from data bases and print media.

Unrecordable Video (Andrew B. Lippman)

The "Unrecordable Video" project addresses video image processing for copyright protection. Past work on generating video formats that are viewable but not recordable is being extended to include copy-protection and encryption and signature information into distributed video information.

Adaptive Color Coding (Walter R. Bender)

This project continues a program of research in color coding that deploys semantic information processing in order to reduce the data storage requirements of photo-realistic, computer displays. Currently, the focus of inquiry is an examination of both temporal and spatial frequency has been used to bias the statistical analysis colors found in full color images. In addition to improving color compression algorithms, the project has developed techniques for making high resolution video stills by trading temporal resolution for spatial resolution.

Hard News (Walter R. Bender)

An investigation of the technology necessary for printing in the home in anticipation of electronic delivery of newspapers and magazines. Issues are quality, formatting and delivery. The translation of broadcasts into print is another area of investigation, as is the personalization of hard copy access.

Personalized Newspaper (Walter R. Bender)

The goal of this research is the development of publications from a broadcast medium to a conversational one. Large-scale optical storage and broadcast channels are the carriers of both the data and illustrations that are edited and perused while they are read by their ultimate recipient. Current work addresses news information systems. The news copy is read through an interaction with a personally dedicated computing resource that mediates between a superset of information and the interests of the particular reader. In addition, it serves as a composition aid and keeper of notes.

Spread Spectrum Technology (Professor Jerome B. Wiesner)

In this application, spread spectrum technology is concerned with communication over a power line bus and deals with the issue, that since power lines are designed for the transmission of electrical power and not data, load noise is very high. This project has been addressing the feasibility of establishing a two-way data transmission facility over this medium.

Wide-Angle Synthetic Holograms (Professor Stephen A. Benton)

A combination of distortion control by digital image pre-processing and the development of new optical techniques is making possible the production of white-light viewable holograms with an angle of view exceeding 90 degrees from side to side.

Edge-Lit Holograms (Professor Stephen A. Benton)

A three-step holographic process has been adapted to allow the holographic illumination to be introduced from the edge of the hologram, permitting a very simple and compact display geometry.

Holographic Color Control (Professor Stephen A. Benton, Ms. Julie Walker)

A system for the chemical pre-treatment of holographic emulsion, and controlled swelling during their exposure, offers the possibility of an automatic process for full-color holographic imaging of natural and computer-generated scenes.

Electronic Holography (Professor Stephen A. Benton)

A reduction of the information in a hologram to the minimum necessary for visual purposes has made possible the development of an acousto-optical light modulator and spinning polygonal mirror laser system for the display of modest holographic images. We believe that this is the first time that holographic images have been computed, transmitted, and displayed in real time.

HUMAN INTERFACE

Human Interface research in the Media Laboratory spans all the significant modalities of human/computer interaction, including research into combination of speech, gesture, and eye input/output. It encompasses the exploration of techniques to support capture of speech and both gestural and gaze outputs from the human user. It addresses the development of machine intelligence to interpret such outputs from the person and maps them to an appropriate response, usually some action in graphics and/or sound (including speech).

Eyes As Output: Eyes in Multi-Modal Computer Dialogue (Dr. Richard A. Bolt)

This research is currently exploring and evaluating eye movements in human/computer dialogue, both alone and in combination with speech and manual pointing. The emphasis is on looking behavior as evidence of interest and attention and as a means of reference.

Knowledge Based Animation (Professor David Zeltzer)

The long term research goal of this project is the design and implementation of an intelligent animation system which will allow non-expert users to define and control the behavior of realistic, articulated figures in complex, simulated environments. The past year saw continued development of motion control systems based on inverse kinematics and the simulation of Newtonian mechanics. These programs have been integrated into a larger software system which now supports the animation of a simulated world that is austere in the number and complexity of objects, but at the same time exhibits many of the familiar physical properties of the world around us, including mass, gravity, and simple creatures that walk and avoid obstacles on their own. The uniqueness of this program comes from its emphasis on the intelligence and physics embedded in the modelled systems, and the integration of these simulation tools with 3D interaction techniques.

Data Glove (Professor David Zeltzer)

This project stems from the development of novel 3D interaction techniques and has resulted in the implementation of a gesture-driven interface to a computer graphics environment, which makes use of a newly available product, the Dataglove. This glove, which is worn by the user, allows the computer to model the movements of the human hand. This interface for computer graphics makes it possible for users to directly manipulate virtual objects in these simulated environments.

Tactile Simulation/Force Feedback Joystick (Professor David Zeltzer/Professor Woodie Flowers)

The aim of this project is the development of human interfaces which provide realistic, real-time three-dimensional tactile simulation of computer-generated objects and environments. The current device takes the form of a joystick, which can move freely in three-space.

NSF-Sponsored Animation Workshop (Professor David Zeltzer)

Aside from one or two very large, national conferences, the field of computer graphics suffers from a lack of small, focussed technical meetings. To help remedy this situation, Professor Zeltzer convened and chaired a workshop at the Media Laboratory -- supported in part by the National Science Foundation -- on the Mechanics, Control and Animation of Articulated Figures. This was a multi-disciplinary workshop of approximately twenty leading researchers in graphics, psychology, robotics and mechanical engineering. The meeting enabled the attending researchers to become familiar with results and methodologies across disciplines, providing for an open exchange of ideas in an area of growing interest, and perhaps most significantly, providing the basis for potentially fruitful collaborations in the future. Position papers were solicited from each participant, and arrangements for publication of workshop proceedings -- tentatively titled MAKING THEM MOVE: MECHANICS, CONTROL AND ANIMATION OF ARTICULATED FIGURES -- by Morgan Kaufman Publishers, Inc., are underway.

Font Scaling (Walter R. Bender)

Most digital typography systems have avoided addressing the problem of non-linear scaling of fonts. Character shape changes as the scale of the character changes. This is done both to exaggerate the relative size of important features as characters get smaller and to compensate for relative resolution changes in the display device.

The particular approach to the the problem we are taking is the use of energy minimizing splines to define individual character contours. Forces are then applied to these splines which appropriately deform the contours. This work should result in efficient methods of automatically doing non-linear scaling of fonts. It can then be applied both to CRT and hardcopy display systems.

Computers and Telephony (Christopher M. Schmandt)

Computer workstations can provide a much needed user interface to advanced telephony functions, provided a path exists between the workstation and switch. Removing user profile information to the office allows a greater degree of personalization and dynamic call handling. This project is being implemented in the ISDN environment of MIT's campus telephone network.

Desktop Audio (Christopher M. Schmandt)

This project explores software architectures and user interfaces to voice as a computer data type as well as a command channel. Its goal is to make speech ubiquitous to a range of applications, for instance, editing a telephone message to include as annotation of a text document. Related issues include object oriented manipulation of multiple media "selection" (or "clipboard") data between processes.

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Back Seat Driver (Christopher M. Schmandt)

The "Back Seat Driver" is a computer program that rides along with you in the car, keeping track of your current position, giving you spoken directions to the destination of your choosing. The Back Seat Driver's speech depends upon how well you follow the route, and it is prepared to make new plans if you fail to follow its instructions.

Synthesis of Affect: Attitudes to Conversation (Christopher M. Schmandt)

The "Synthesis of Affect" project seeks rules for expressing emotional states with synthetic speech. These rules tell how to derive abstract parameters for intonation and voice quality from a representation of affect, and how to program a speech synthesizer to convey these tones of voice.

Voice Windows (Christopher M. Schmandt):

In this project we are building a speech recognition interface to a window manager in the X window system. The utility of speech recognition in this context will be evaluated by studying its use among laboratory student programmers, using logging, interviewing, and video taping techniques.

Network Based Voice Services (Christopher M. Schmandt):

This project explores the utility of voice in a range of applications of offering services to users of the telephone network. Topics being examined include: voice mail, speech synthesis of electronic mail, access to calendars and rolodexes, and speech based user interface to call processing features such as variable call forward.

APPLICATIONS OF MEDIA TECHNOLOGY

The applications of Media Technology are as varied as the technologies being assembled to serve them. The following list, drawn from education (primary through tertiary), mapping, medical imaging, transportation, and the performance arts, illustrates this variety.

Society of Mind (Professor Marvin Minsky)

Professor Minsky continues to develop the theory of human thinking and learning called the "Society of Mind". This theory explores how phenomena of mind emerge from the interaction of many disparate agencies, each mindless by itself. For example, one aspect of the theory explains 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 a continuing interest in the limits and potentials of "connectionist learning systems" and their role in distributed cognitive accounts like the Society of Mind. He is actively considering how such systems may be combined and interconnected in a way that avoids the serious scaling problems of unstructured connectionist systems.

Animal Construction Kits (Professor Marvin Minsky)

This is a project whose context is the simulation of animal behavior, with explicit goals of developing computational models for ethology, investigating situated action approaches to artificial intelligence, and providing an educational environment in which grade-school children can experiment with behavioral mechanisms and create autonomous characters. The animal construction kit will allow novice programmers to assemble active artificial components, with sensors, muscles and other effectors.

Meta-Media, a Multi-Media Authoring Testbed (Professor Muriel R. Cooper and Ronald MacNeil)

The Meta-Media project integrates a rich set of graphic tools and editors with searching, browsing, linking, scripting, and visualization capabilities to allow research into the new design issues emerging from real time, multi-layered information in an electronic communication environment.

The planning of structured and unstructured informational multi-media pathways presents graphical design complexity and challenge for both the designer and user of multi-media information. Traditional media designers from the print, audio-visual and animation worlds provide important insights into guiding viewers' perceptual responses to information.

Work that bridges the gap between the "hands-on" world of designers and the more abstract symbolic world of programming explores spatial, temporal and relational rules and methods which rank information for the viewer, influence emotional responses, and often embody hidden aesthetics. Automatic layout and design intelligence will be required to filter data for users in every field.

Topographical Typography / Dynamic and Intelligent Graphics in Mapping (Professor Muriel Cooper and Ronald MacNeil)

The typographical and graphical conventions found in conventional mapping represent hierarchical abstractions of complex analogue information and provide the viewer with ways of comprehending information for decision making.

The goal of this project is to develop dynamic maps, typography, and graphics which have knowledge of each other, and to develop intelligent tools that allow the effective design of graphical behavior in relation to real-time dynamic data. For example, as the word SNOW moves across a terrain, it changes in size and translucency in response to real-time weather data from a satellite.

Tone of Voice Typography (Professor Muriel R. Cooper and Ronald MacNeil)

This project explores the relationships between the spoken and seen word. Typographical style in print has long been a substitute for sound and dynamics. The new capability of integrating them dynamically points to a new vocabulary supported by such tools as real-time scaling of text, translucency and pressure input, size-driven by pitch. For example the color, size, translucency, a style and even meaning of a word may be driven by the pitch of a sound over time.

Design Constraint System (Ronald MacNeil)

TYRO the (very novice) Graphic Designer's apprentice is a visual programming environment to support the exploration and evolution of graphic design concepts. The basic unit of design knowledge, the prototype, is represented as a network of constraining relations with assertion rules. Similarly, a design is a constraint network of prototypes with its set of assertion rules.

The environment supports multiple simultaneous perspectives on each object (Logical, Spatial, and Hierarchical browsers), and a variation generator for exploring the design space and discovering the assertion rule break-points.

Graphics for Software Visualization (Henry Lieberman)

This project explores how modern computer graphic imagery can be used as a tool to help programmers visualize software. We are implementing a range of experimental debugging systems that use color, animated typography, and three-dimensional visual representation of programs.

Intelligent Assistants for Visual Problem Solving (Henry Lieberman)

Experts in visual domains such as graphic design are fluent in the generation and critique of visual examples. We are combining representation and learning techniques from artificial intelligence with interactive graphical editors to create a "programming by example" system to assist designers in automating graphical procedures.

Visual Information System (Professor Patrick A. Purcell)

The Visual Information System is an ongoing project whose primary aim is to provide the graphic workstation user with access to images on the same scale and with the same richness of provision as text users expect to access data bases and online bibliographies. The user interface at the work station now incorporates facilities for playback of video and campus cable TV in addition to the retrieval of still frames from image libraries, which still represents the current focus of the visual information system.

Interactive Cinematics (Professor Glorianna Davenport)

The goal of this project is to develop multimedia editing and presentation systems which offer the user flexible and provocative methods of story construction. Projects include an object oriented graphical interface for virtual editing, constraint-based video sequencing, and dynamic links for temporal media.

Elastic Movies (Professor Glorianna Davenport)

Explorations into the form and content of new interactive cinema. Current projects include: an interactive multimedia journal, "The Elastic Charles," our hypothetical issue of the American River Magazine; documentary movies as an educational resource, "City in Transition: New Orleans 1983-1986"; and multi-track narratives, "Intrigue at Rowes Wharf."

Advanced Interactive Mapping Displays (Professor Edward H. Adelson, Walter Bender, Dr. Richard, Professor Stephen A. Benton, Professor Muriel R. Cooper, Ron MacNeil, Professor Alex Pentland, Professor David Zeltzer)

A 3-year effort commenced in January 1989 to investigate issues surrounding mapping display technology and interaction with map displays. This project involves personnel from six groups across the Media Laboratory. Focal issues include: Print Quality Maps; Multi-Modal Reference; Vehicle and Terrain Animation; Terrain Analysis; Holographic Terrain Mapping; XYT Process of Image Data; Advanced Typographics for Mapping.

Hyperinstruments (Professor Tod Machover)

Hyperinstruments is a project which attempts to define and produce what we consider to be the models for musical instruments of the future. These prototypes combine new definitions of musical virtuosity with intelligent machine understanding and music structure generation. This past year, much development has taken place to extend and enrich the Hyperinstrument systems that were used for Machover's VALIS opera, including the construction of entirely new performance systems. Our "Hyperlisp" environment was turned into a general research tool, and is currently employed by various researchers at the Media Lab and at various other centers and institutions. An automated music generation and analysis system, CYPHER, was developed and tested in a number of musical contexts. An environment was established to turn acoustic signals into "hyperinstrument" controls (MACH 5). Various music cognition studies (into phenomenon such as beat and phrase tracking) have yielded intelligent algorithms which have been incorporated into our systems. Several new musical compositions have been produced and performed throughout the world using our "hyperinstruments".

Parallel Computation of 2-D Fourier Transforms (Professors Steven Benton)

The principals of the Fast Fourier Transform are being adapted to a massively parallel SIMD computational architecture as a further step toward interactive electronic holography.

Synthetic Holography for Computer-Aided Design (Professor Stephen A. Benton)

The extension of advanced cues to shape in realistic imaging, such as reflections of the environment, to include the parallax of holographic images, has proven important in the effective pre-visualization of complex engineering designs, especially when combined with the wide angle of view offered by new hologram types.

Holograms for Medical Imaging (Professor Stephen A. Benton)

The combination of high visual quality in synthetic holograms and new developments in the "volumetric rendering" of MRI medical data makes possible the representation of very complex nested three-dimensional structures. Controlled transparency of outer tissue layers, and especially the reflection of light from them as the viewer moves, has proven important in the comprehension of their spatial relationships to deeper structures.

The Synthetic Performer (Professor Barry Vercoe)

Real-Time Computation in Contexts of Skilled Human Performance. Development of synthetic human performance by putting computer systems in position of highly sensitive human interaction. A synthetic musical instrument will be introduced into a close-knit performing ensemble without disturbing its normal musical behavior. The project involves tracking human performers (finger, sound), extraction of tempo, loudness and stylistic information, then construction of control processes to manage flexible real-time audio processing.

Synthetic Listeners (Professor Barry Vercoe)

Audio signal separation, with a focus on polyphonic pitch detection. This research seeks to understand how humans manage multi-source audio separation with apparent ease (the "cocktail party conversation" trick), and why machines cannot. We are developing new models of digital audio processing based on the massive parallelism of the ear and auditory cortex, in the hope of enabling machines to deal with complex audio signals the way humans do.

The Artificial Acoustic Ambience (Professor Barry Vercoe)

An investigation of electronic enhancement of a room's natural ambience by creating an "active boundary" of electronic sound reflections via a set of microphones and speakers placed around the room. The technique will utilize a new class of flat reverberators running on a central very-high-speed digital audio processor. The goal is to separate acoustics from architecture in the design of public spaces.

Looking At People (Professor Alex Pentland)

A new project begun in the Vision Science Laboratory called "Looking at People." Current topics include the following: (1) Tracking people's body positions as they point and move about in the work environment; (2) "Lip reading" e.g., augmenting auditory speech recognition with visual cues; and (3) Person identification, principally by recognition using the relative size and position of facial features and body parts.

Exploratory Design and Visualization: Virtual Manufacturing (Professor Alex Pentland)

The role of computers in the mechanical design process is currently limited to drafting and, if expert systems prove useful, helping routine design detailing. Their great potential for analysis is largely limited to checking single pieces of already-completed designs. The most glaring defect in this situation is that the critical early stages of design --- where different designs are compared and the general outlines of the final design are fixed --- are conducted without computer

support. We argue that computers can fundamentally change and improve the design process by allowing interactive exploration of the space of valid designs. Computers can accomplish this by providing a drawing medium whose agility is comparable to pencil and paper, and which allows real-time structural and dynamic analysis of the entire system as it is being designed. We are working to solve the fundamental computational problems posed by this goal, and have developed a prototype system which has already demonstrated significant promise.

Constructionism: A New Opportunity for Elementary Science Education (Professor Seymour Papert)

The hallmark of this project exists as an intimate connection between the development of new technological objects and the facilitating of their appropriation by individuals and cultures in an educational setting. One such major setting is the Hennigan School located in the precincts of Boston.

Using Computers to Combat Illiteracy (Professor Seymour Papert/Stephen J. Ocko)

Research on how the computer presence can enter the school culture. The program includes the development of a process-control computer (the "Programmable Brick") small enough to be part of a child's scale model.

Children as Cyberneticists (Professor Seymour Papert/Professor Edith Ackermann)

The focus of this project deals with the concepts of control and communication in early learning. It launches a research program on "cybernetic thinking" in children, which includes both the study of elementary forms of control engineering using the Logo Brick and other modules.

LEGO/Logo (Steve Ocko)

This project aims to create environments in which children can act like inventors. Current work focuses on the development of "electronic LEGO bricks" with microprocessors or other electronic components built inside. Just as children can build structures with existing LEGO bricks, they can build "programs" or behaviors by wiring these new electronic bricks together. Applications include the development of "cybernetic animals."

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MEDIA LABORATORY SPONSORS

The following list indicates Media Laboratory Sponsors according to the categories of sponsorship defined in Intellectual Property Rights of the Media Laboratory.

Major Endowment

International Advanced Research
& Development Institute

Endowment

Asahi Broadcasting Corporation
Fukutake Publishing Corporation
Interlego A/S
NEC Corporation
Toshiba Corporation

Research Contracts

Ampex Corporation
Apple Computer, Incorporated
AT&T
Capital Cities/American
Broadcasting Company (ABC)
Columbia Pictures Industries, Inc.
Control Data Corporation
Defense Advanced Research
Projects Agency (DARPA)
Ford Aerospace
General Instrument Corporation
General Motors Corporation
Hewlett-Packard Company
Home Box Office (HBO)
Hughes Aircraft Company
International Business Machines
Interlego A/S
Eastman Kodak Company
John D. and Catherine T. MacArthur
Foundation
National Broadcasting Company(NBC)
National Science Foundation (NSF)
NEC Home Electronics Ltd.
Nippon Hoso Kyokai (NHK)
Nippon Telegraph & Telephone (NTT)
NYNEX Corporation
Paramount Pictures Corporation
Public Broadcasting System (PBS)
Sun Microsystems, Inc.
Tektronix, Incorporated
Thinking Machines Inc.
US West Advanced Technologies, Inc.
Warner Brothers, Incorporated
Yamaha Corporation
Zenith Electronics Corporation

Nicholas P. Negroponte

Media Technology Group

Ameritech
Apple Computer, Incorporated
BellSouth Corporation
Control Data Corporation
Electronic Data Systems/CMI
Fujitsu Laboratories, Ltd.
Hughes Aircraft Company
Lotus Development Corporation
McCann-Erickson Worldwide
The MITRE Corporation
Olivetti
Pioneer Electronic Corporation
Roland Corporation
US West Advanced
Technologies, Inc
Xerox Corporation.

Major Equipment Gifts

Apple Computer, Incorporated
Digital Equipment Corporation (DEC)
Gould Electronics
Hewlett-Packard Company
International Business Machines
New England Digital Corporation
Sony Industrial Products
Sun Microsystems, Inc.
Wang Laboratories Incorporated

Building Gifts

American Broadcasting Company
Asahi Broadcasting Corporation
Asahi Shimbun Publishing Company
Columbia Pictures Industries, Inc.
Computervision Corporation
Dow Jones & Company, Incorporated
Eastman Kodak Company
Hitachi, Ltd.
Matsushita Electric Industrial Company
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The Mead Corporation
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NEC Corporation
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Schlumberger
TIME, Incorporated
The Times Mirror Foundation
Warner Communications, Incorporated

SCHOOL OF ENGINEERING

As a leading technological university, MIT occupies a position of unusual responsibility in our increasingly technological society. It and its sister institutions share the opportunity and the burden of educating the young people who will provide engineering leadership in the future. MIT's engineering graduates will be called upon to invent, design, develop and produce increasingly sophisticated technology to satisfy the needs and desires of the U.S. and the world populace, in ever more intense competition with their peers in other industrialized countries. They will not be sheltered from this competition by U.S. dominance of the world market, as they once were. They will have to compete through full exercise of their wit and industry. MIT's graduates will be called upon by society to meet these challenges while ensuring that the habitability of the globe and its ecology are not deteriorated by the omnipresent machines, the processes which produce them or the fuels on which they feed. They will also be expected to share in the worldwide responsibility to help improve the lot of those who live in regions of the globe or in sectors of society which have not yet shared the fruits of technological affluence. To ensure that they meet these responsibilities, that they take full advantage of their opportunities, MIT's graduates will have to exercise fully their prerogatives as citizens, making their views known to society at large and using their influence for the good of society in the largest sense.

As society changes its goals and aspirations, so must engineering change its foci and perspectives. It is paramount that those responsible for engineering education and research periodically reevaluate their efforts. Today with the unrelenting pace of technological change, some activities require bold changes, others subtle reformation, and yet others, only reaffirmation of their value. It is in recognition of these background forces that the MIT School of Engineering has begun the development of a long range plan suitable to lead us into the twenty-first century. Our aim is to define the characteristics of the Engineers of the Future, and the educational processes which will nurture these characteristics in our students.

Following extensive reviews within each department and a pair of two day meetings of a Long Range Planning Group, the School has agreed upon a new statement of its mission, a set of school-wide initiatives which will aid in its discharge and a consensual basis upon which the departments and laboratories have prepared their long range plans.

The School takes its mission to be: to prepare men and women through education and research for the imaginative, purposeful and thoughtful creation and utilization of knowledge and technology designed to improve the human condition and maintain the diversity of life on Earth.

While the aspirations and commitments reflected by this mission are not entirely new for MIT, they do reflect shifts in emphasis. One is the explicit recognition that excellence in technical disciplines is not enough, that the School must rekindle its interest and rebuild its expertise in applications of technology, in industrial processes and in nurturing invention. That its research and teaching must take full cognizance of the economic and social interactions of technology and that these are part of the professional responsibility of the engineer of the future represents a new commitment for the School. That the School is no longer content to educate engineers to be silent implementors of policies set by others implies a major commitment to change.

To meet this commitment, the School has concluded that it must broaden the educational experience of its four year graduates while maintaining the technical depth and excellence of their education; that in most departments, the undergraduate degree must perforce be regarded as pre-professional and that, therefore, it is desirable to provide as an option in parallel with the current research-focussed master's programs, a new master's level degree program which will bring students to the professional level required for employment in industry.

Each of the departments has begun to plan such programs; a Committee on Educational Programs will be established to stimulate and coordinate the development of these efforts across the School.

The School desires to continue to work closely with the School of Science and other schools toward a more effective Science Core program for the Institute. While the most important mechanism is collaborative teaching, a Committee on the Science Component of the General Institute Requirements, which is to be established to oversee this collaboration is considered to be an important element for the future.

Through the Center for Advanced Engineering Study, the School intends to facilitate the continuing education of engineers in industry by means of a series of short courses to be made available on campus or by television and through a weekend format for regular MIT subjects.

The School identified the Engineering of Large Systems as a theme deserving of special attention across the several departments and laboratories. To facilitate coordination of their research and exchange of ideas and methodologies a Committee for Research on Engineering of Large Systems will be formed with representation from each of the groups active in this area.

Science, Technology and Policy Studies are of growing interest to the School of Engineering and the School intends to participate fully in any new initiative launched in this area. Meanwhile, it will build on the activities of the Center for Technology, Policy and Industrial Development.

Finally, a Strategic Planning Committee will be formed as a subgroup of Engineering Council to carry forward the work begun during this intensive planning effort. The Committee will identify and study the physical, social, political and demographic changes which affect engineering practice, education and research. Acting in an advisory capacity to the Dean and to Engineering Council, the Committee will assist the School in formulating timely responses to these changes.

Elaboration of each of these points is available at two levels; in the Long Range Plan of the School of Engineering and in the individual Long Range Plans of the departments, laboratories and centers, which are available within the School as addenda to the School's Plan. These plans have been prepared on the consensual base established in the course of the planning process and, therefore, should reflect a greater degree of coordination than has been apparent in the past. As is usual they offer more than can be vigorously pursued. By selecting for emphasis from the programs proposed by the departments those which offer the greatest contributions to its Mission, the School intends to make best use of the material and human resources at its disposal for the education of the engineering leaders of the future.

This section of Reports to the President collects reports from each of the eight departments and ten laboratories and centers which report to the Dean of Engineering. It also contains brief status reports on some few activities and programs managed directly by the Office of the Dean of Engineering.

Enrollment

Undergraduate enrollment in the School decreased again this year, by about 56, with another large decrease in Electrical Engineering offset somewhat by increases in Civil Engineering and Mechanical Engineering. The graduate enrollments also decreased, by about 40, consistent with the School's desire to decrease the workload of its faculty.

Engineering Internship Program

For the summer of 1989, 53 sophomores have been placed in the Engineering Internship Program making the total enrollment 137. There are 33 participating companies.

Affirmative Action

The School continued its policy of offering positions to outstanding women and minority candidates. A key element of this policy is to seek minority and women faculty irrespective of the specific fields authorized for faculty searches. The School also funded postdoctoral positions for minority candidates with good potential to become faculty members.

This year of 15 faculty hires two were women, bringing the total number of women faculty in the School to seventeen.

Minority Introduction to Engineering and Science

In the summer of 1989, 52 high school juniors will attend the MITES program, which introduces them to college level mathematics, physics, humanities, design and chemistry/biochemistry, and to the MIT atmosphere. They become acquainted with MIT faculty and with each other.

The program is directed by Professor Douglas Carmichael and coordinated by Mr. Willilam Ramsey.

Faculty

The School welcomed 15 new faculty this year. With 17 departures, the School's faculty declined by two.

During the year, Professor Robert A. Brown replaced Professor James Wei as Head of Chemical Engineering, and at the end of the year Professor Mujid S. Kazimi replaced Professor Neil E. Todreas as Head of Nuclear Engineering. Professor Joel Moses announced his intention to relinquish the chairmanship of Electrical Engineering and Computer Science effective August 31, 1989, and Professor Paul L. Penfield, Jr. has accepted this position effective September 1.

Dean Gerald L. Wilson began a well earned leave of absence on June 1. He will return on January 15, 1990.

Jack L. Kerrebrock

Department of Aeronautics and Astronautics

Departmental activities have continued in the pattern we are all so familiar with. This year two senior faculty retired. Professor Theodore H.H. Pian joined the Department as a Teaching Assistant in 1946. He joined the faculty in 1952, and became a full Professor in 1966. He is best known as a scholar who may be said to be the father of hybrid finite element analysis. We were pleased to co-host a meeting in honor of his 70th birthday in March of this year. Professor Judson R. Baron came here as a graduate student in 1948, was appointed an Assistant Professor in 1957, and became a full Professor in 1965. His primary technical contribution has been in the application of modern computing to fluid mechanics. His thesis studies were based upon the use of the Whirlwind Computer to solve two gas boundary layer problems including heat transfer. Subsequently, he had the satisfaction of seeing his predictions confirmed by careful experiments conducted by Jacques A.F. Hill and Frank H. Durgin, who is currently the Associate Director of the Wright Brothers Facility. Professors Pian and Baron have made many contributions to the Department through serving as advisors, departmental committee chairmen, and through their excellent teaching. We shall also miss Assistant Professor Steven Bussolari, for his contributions to Human Factors and for the outstanding job he did as Director of Flight Operations for the Daedalus Project. We wish him well in the future.

Professor Martin Landahl has been away on sabbatical leave, and will return this September. Professor Manuel Martinez-Sanchez went to the Ciudad Universitaria, Escuela Tecnica Superior de Ingenieros Aeronauticos in Madrid for his sabbatical leave this spring term. Professor Robert Simpson is on sabbatical leave for the calendar year 1989. We are pleased to report Associate Professor R. John Hansman was awarded tenure as of July 1, 1989.

We are pleased to report that NASA Headquarters has selected and funded our proposal for a Space Engineering Research Center. Congratulations are in order to Professors Mar and Crawley of the Space Systems Laboratories. Professor Crawley has been named Director of this Center.

As of July 1, 1989 the Department faculty will consist of 20 full professors, including Dean Jack L. Kerrebrock and Professor Shaoul Ezekiel (the Director of the Center for Advanced Engineering Study), seven associate professors, and eight assistant professors. We are currently one under our complement contained in the Dean's manning table.

This year saw the renewal of the Department Seminar Series. Each of the Divisions were responsible for inviting an outstanding speaker who gave a general seminar. The average attendance was high, well over a hundred. On two occasions, Room 35-225 was so full attendees were sitting in the aisles. The schedule of seminars is given below:

September	The National Aerospace Plane - The Sky is no Longer the Limit Mr. Howard T. Wright, NASP Program Office.
October	Winged Wonders - History of the Flying Wing Mr. E.T. Woodridge, National Air and Space Museum.
November	Human Performance in the Transportation Safety System Mr. John Lauber, National Transportation Safety Board.

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February	National Aeronautical Research and Development Goals Professor Robert Stengel, Princeton University.
March	Milestones in Gas Turbine Engine Development Donald Jordan, Pratt and Whitney, Retd.
April	Returning the Shuttle to Safe Flight Mr. Allen McDonald, Thiokol Inc.
May	KLM a European Airline in a Changing Environment Mr. Karel Ledebouer, Sr. VP Flight Operations KLM.

Gerhard Neumann, formerly Head of the General Electric Aviation Gas Turbine Division, gave the Gardner Lecture, "Never a Dull Moment". He outlined some of the problems and triumphs in his experience in the development of large gas turbine engines. He emphasized the importance of being able to solve practical problems, even if it involves "getting your hands dirty".

Further, Dr. Richard Battin, Adjunct Professor of Aeronautics and Astronautics, gave his von Karman Lecture, "A Funny Thing Happened on the Way to the Moon".

This year the Jerome Clark Hunsaker Visiting Professor was Dr. Joseph F. Shea, Senior Vice President, Technology, Raytheon Company. His experience proved valuable in his work with Professor Akin in teaching Space Systems Engineering. Professor Shea also gave the Minta Martin Lecture, "Evaluation of National Technical Programs". In this talk, he offered a means of comparing the future of large scale technical developments, like the space station, in terms of past successes and failures.

We joined with the Program in Science, Technology and Society to sponsor a series of seminars on National Space Policy given by Dr. Albert Wheelon, who recently retired as Chairman and CEO of Hughes Aircraft. We were pleased that Dr. Wheelon joined our faculty on several occasions and took part in our deliberations.

The Wednesday noon Faculty Luncheon meetings continued to be valuable to the faculty in several ways, including stimulating communication between faculty members. Professor Winston Markey did an outstanding job of organizing an interesting and timely series of discussion subjects, focusing on long term aspects of undergraduate education.

In addition, the student branch of the AIAA sponsored an Industrial Opportunities Seminar to help graduating seniors understand the technical environment in several industries.

Finally, the department took part in Technology Day this Alumni Week. The central theme was the 20th Anniversary of the first manned landing on the Moon. We are pleased that both our faculty and our alumni have played a leading role in the exploration of space.

UNDERGRADUATE PROGRAM

As shown in the table below, the undergraduate enrollment increased slightly this year, suggesting our enrollment has more or less stabilized. The total enrollment is also about the same as it has been over the last three years.

TABLE
Undergraduate Enrollment over the Last Seven Years

	1982-3	1983-4	1984-5	1985-6	1986-7	1987-8	1988-9
Sophomores	86	100	99	106	120	96	103
Juniors	86	81	90	92	103	118	94
Seniors	85	81	93	106	98	105	130
Totals	257	262	282	304	321	319	327

The current fraction of women in the graduating class is 0.16 which is equal to last year's fraction of 0.16. The current average women's enrollment for all three classes is 0.20.

Mr. Matthew A. Machlis was selected for the Doolittle Scholarship Award. His outstanding academic record and contributions to the department made him the successful candidate. He continues the tradition of excellence for the Doolittle Scholarship holders.

Other undergraduate awards are listed below:

HENRY WEBB SALISBURY AWARD

This award established in the memory of Henry Webb Salisbury('33) is given annually to a graduating senior in Course 16 for the highest degree of academic achievement. This year's winners are:

Andrew Kevin Barrows	'89
Claudio de Carvalho Chamon	'89
Scott Alan Geels	'89
Ted Adam Manning	'89

JAMES MEANS MEMORIAL PRIZE

For excellence in Flight Vehicle Engineering

Andrew Kevin Barrows	'89
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For excellence in Space Systems Engineering

Sayan Chakraborty	'89
Charles William Whetsel	'89

ADMIRAL LUIS DE FLOREZ AWARD

Award to undergraduates who have demonstrated "original thinking or ingenuity" in Aeronautics and Astronautics. This year's winners are:

Christopher Richard Doerr	'89
Kedron Rayner Wolcott	'90

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Toni El-Dirani	'90
Zev Leon Waldman	'90

Jeffrey Travis Myers	'89
Claudia Ute Ranniger	'89

Dana Keoki Jackson	'89
Eugene Allen Magnier	'89

Nathanael Fuller Seymour	'89

Joseph Charles Pellegrini	'89

UNIFIED ENGINEERING AWARD

Andrew Kevin Barrows	'89
Gerald Keith Colmer, Jr.	'89

NATIONAL SCIENCE FOUNDATION SCHOLARSHIP

Harris L. Edge	'89
Angel R. Perez	'89
Cristina D. Vilella	'89

About one-third of the faculty continues to be actively involved with freshman in one way or another. We are pleased that the department's commitment to this important activity remains strong.

GRADUATE PROGRAM

The number of graduate students continues to decrease slowly, in accordance with our plans to reduce the number of students to about 180, or about five per faculty, on the average. The current level is 197 compared with 230 about five years ago.

FACULTY RESEARCH ACTIVITIES

The faculty research effort is divided along the lines of the teaching divisions and will be described in that order below:

Bioengineering; Man Vehicle Laboratory; Professor Young and Dr. Oman continue to be active in Vestibular Research for NASA Manned Space Flight Office. They are preparing for another inflight experiment that could be launched in 1992. Professor Young has embarked upon an exciting parallel program. His goal is to apply techniques of Artificial Intelligence to provide the ground based investigator with a rational means of controlling an inflight experiment as the data is monitored in real time, and reviewed for the purposes of making decisions for a change in protocol. In effect this approach, if it proves practical, will have the effect of allowing the ground based investigator to act as if he were present working with the inflight subject.

Fluid Dynamics Laboratory; Professors Landahl and Widnall are continuing their research in the origin of boundary layer transition from laminar to turbulent flow, and the character of turbulence. As a consequence of this work Dr. Haritonidis, with their support, has derived the "Law of the Wall" from unsteady turbulent flow properties.

Computational Fluid Dynamics Laboratory; Professors Baron and Murman have continued their research in code development. Their success with self-adaptive grid generation has proved to be of value in both transonic and supersonic flows over delta wings. Professor Giles has successfully developed a new method to calculate various rotor-stator interactions. Note this is a cooperative effort with Professor Epstein.

Gas Turbine Laboratory; Three recent advances of importance in this Laboratory are related to unsteady flow phenomenon in tracking. Professor Alan Epstein measured unsteady flow properties in turbomachinery and found the efficiency of such machines may be misrepresented. Note this is part of a cooperative effort with Professor Giles. Another advance has resulted from Professor McCune's generalization of classical unsteady wing theory to large motions. Thus a specific wing response to a given maneuver can be evaluated in real time.

Professor Greitzer is leading an effort to understand the factors that govern stability limits in Centrifuge Compressor Diffusers.

There is a broad gauge effort involving all the Gas Turbine Lab Faculty and Professor Lena Valavani of the Instrumentation, Guidance and Control Group to explore new ways to use distributed intelligence, sensors and actuators in gas turbine engines. This is the so-called "Smart Engine" program, and may well yield the most significant long term results of any program in the Gas Turbine Laboratory.

Instrumentation Guidance and Control; The research in this division is characterized by many cooperative efforts with other faculty groups. I expect this trend to be increasingly important as the idea of controlling situations that were previously regarded as static or passive becomes more wide spread. Examples are listed below:

Professors VanderVelde and Hall's use of sensors and actuators to control the ships large space structures are part of the Space Engineering Research Center activities.

Professor Hollister - Studies of application of modern technology to Terminal Area Air Traffic Control Systems (Flight Transportation Laboratory).

Professor Valavani - "Smart" Engine Control Technology (Gas Turbine Laboratory).

Professor Hansman - Aircraft Icing Research, including development of inflight instrumentation (Flight Transportation Laboratory).

Professor Alexander - Uses of remote devices for erection of space structures (Space Engineering Research Center).

Structures and Materials; Professors Lagace and Graves are conducting research on Damage Tolerance and Longevity Methodologies for various composite aircraft structures (Technology Laboratory for Advanced Composites).

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Space Engineering Research Center; Professors Crawley and vonFlotow are studying the dynamics of deformation of large space structures, with a goal of being able to control the deformation and reduce dynamic loads that could interfere with micro-gravity experiments.

Finally, the Systems Division faculty's research is divided into two categories; aircraft systems and space systems. The aircraft systems research is currently in the Flight Transportation Laboratory and the VTOL Technology Laboratory. In the former, Professors Odoni and Simpson are conducting research in Airline Seat Inventory and Yield Management and Ocean Separation Standards. Professors Ham and Drela are conducting research in air loads on helicopter rotors and application of this information to the reduction of the vibrations generated by the rotor.

The Space Systems Laboratory has a wide range of activities ranging from interaction of high voltage surfaces with the space environment (Professor Hastings) to Magneto-plasma-thrusters (Professor Manuel Martinez-Sanchez) and the Optimization of Space Systems. The project currently generating the most interest is Professor Akin's concept for a new technique for spacecraft re-entry and recovery. This scheme is based upon a deployable radiation cooled shroud (it looks like an umbrella, convex side to the wind). This light weight system will be tested in August and is based upon the fact that deceleration at higher altitudes reduces the heat load since the gas is rarer.

The research activities in the Department are sufficiently broad that I have not discussed one project in ten here. Descriptions of the entire Department Research Program may be found in the Industrial Liaison Program Directory.

FACULTY NOTES

Professor E.F. Crawley - Associate Editor of the AIAA Handbook of Astronautics.

- Associate Editor of the Journal of Intelligent Structures and Materials.

Professor R. John Hansman, Jr. - Became Associate Fellow of the AIAA.

Professor Winston R. Markey - Department Teaching Award for 1988-89.

Professor Paul A. Lagace - Departmental Teaching Award for 1988-89.

- Published a book: Composite Materials: Fatigue and Fracture, 2nd Volume.

- American delegation to the Soviet Union for the 1st US - USSR Symposium on Composite Materials.

Professor Michael Graves - Named Boeing Assistant Professor of Aeronautics and Astronautics

Professor Karl U. Ingard - Received the Per Bruel Gold Medal for Noise Control and Acoustics.

Professor Daniel E. Hastings - Martin Marietta Energy Systems Award for a Superior Paper.

Professor Richard Battin - Conducted a two-day short course: "Introduction to the Methods and Mathematics of Astrodynamics" for the Guidance, Control and Astrodynamics Conference of the AIAA.

Professor Michael Giles - Invited to teach a short course at von Karman Institute in Brussels.

- Member of the AIAA Technical Committee on Interactive Graphics.

Professor W. VanderVelde - Graduate Student Council Teaching Award.

EUGENE E. COVERT

Department of Chemical Engineering

The 1989 academic year was filled with milestones in the Chemical Engineering Department. The Department celebrated the Centennial of Chemical Engineering at MIT in October of 1988. Beginning in the Fall our new Integrated Chemical Engineering subjects were offered on a trial basis. In January, Professor James Wei stepped down after eleven years as Department Head and Professor Robert A. Brown assumed the position.

The celebration of the Centennial of Chemical Engineering was divided into a two-day symposium on the future of Chemical Engineering and a Convocation of the Centennial. The symposium was held on Cape Cod and members of our faculty were joined by 33 distinguished educators and industrial researchers from all over the world. Vigorous discussions, initiated by the presentation of position papers, covered the important areas of chemical engineering research and education. The proceedings of the meeting will be published in the series *Advances in Chemical Engineering* by Academic Press later this year. The Convocation of the Centennial was held on Saturday, October 8th and consisted of a symposium of plenary talks about the history and future of chemical engineering, an open house including research presentations and laboratory tours in the Landau Building, and a gala celebration held at the Museum of Science on Saturday evening which brought together more than 800 alumni and guests from all over the world.

We have begun implementation of the new design subjects "Integrated Chemical Engineering," or ICE, as the capstone design subjects for our senior undergraduates. These subjects, 10.361 and 10.362, were taught on a trial basis in the fall and spring and received excellent reviews from the students who participated.

Professor Jefferson Tester has stepped down as Director of the School of Chemical Engineering Practice after serving 8 years, during which time the program was rebuilt to its former stature as one of the premier educational programs at MIT, to become Director of the Energy Laboratory at MIT. Professor T. Alan Hatton has taken the position of Director of the Practice School and will be assisted by Professor Jeffrey Feerer who comes to Cambridge after three years as Director of the Practice School Station at Dow Chemical. The Practice School continued to operate major stations at Dow Chemical Company in Midland, Michigan and General Electric Corporation in Albany, New York. Other stations will be run during the summer of 1989 at Syntex Chemicals in Boulder, Colorado, and at Chevron in Richmond, California. The new station at Chevron marks the beginning of a long-term commitment for a summer Practice School station. Fund raising for endowment of fellowships for the Practice School has continued; however, the rate of increase in the total has slowed considerably. Currently we have raised approximately \$5.3 million, compared to \$5 million last year, of the \$8 million goal.

There were two retirements in the Department during the last year, and one new faculty member will join us soon. Professor Raymond F. Baddour and Professor Marcus Karel retired from the active faculty. Marcus left to become chair in the Rutgers University World Class Scholar Program as State of New Jersey Professor of Food Science. Klavs F. Jensen will join the Department as a Professor in the Fall of 1989. Klavs is an expert in the chemical reaction engineering of advanced materials processing, especially in chemical vapor deposition systems for microelectronics fabrication. He will add depth and breadth to our teaching and research programs in these areas.

UNDERGRADUATE EDUCATION

The following table shows the trends in undergraduate enrollment:

	84-85	85-86	86-87	87-88	88-89
Sophomore	61	49	43	38	47
Junior	47	69	49	36	36
Senior	115	54	65	55	47
TOTAL	223	172	157	129	130

Sophomore enrollments have started to increase from the minimum of 38 experienced in '87 - '88 toward the more optimal level of between 60 and 80. We project a sophomore class of approximately 60 for '89 - '90. Two changes in the undergraduate curriculum last year were the introduction of a six unit introductory computer subject, 10.001, and two new integrated chemical engineering (ICE) subjects, 10.361 and 10.362. By reducing the scope of the introductory computer subject from the former 12 unit 10.01, it was possible to offer 10.001 both in the fall semester and during IAP. Student response was very positive, particularly to the opportunity to take a required subject for credit during IAP. The ICE subjects were a more significant curriculum change, and are described more fully below.

Update on Integrated Chemical Engineering (ICE)

The new two-semester sequence of subjects 10.361 and 10.362 Integrated Chemical Engineering was offered on a pilot basis to a group of eight Course X seniors who volunteered to take the subjects as electives. Each subject consisted of two or three modules, each about a month in length, and each is devoted to the solution of an engineering problem in the context of specific industrial and environmental settings.

The five modules (and the professors in charge) dealt with the following topics: design a drug delivery system for treating brain cancer (Professor Robert S. Langer); recommend the strategy for cleaning up a toxic waste dump site (Professor Adel S. Sarofim and Dr. John Ehrenfeld); design a new product "Polybeads" for use in biotechnology separation systems (Professor Edward W. Merrill); develop a batch process to manufacture the monomer to produce a high-performance polymer for market trials (Professor Lawrence B. Evans); and design a continuous process to make acetic anhydride from acetone and acetic acid (Professor George Stephanopoulos).

Although the ICE subjects are built around a set of real-world problems, the major objective is to teach the fundamentals of chemical engineering better. The other important objectives are to integrate the various subjects in the students' education, to develop synthetic problem-solving skills, and to enhance professional awareness. The modules can also include more of the new technology areas that chemical engineers are concerned with today.

The pilot presentation of the subject was very well received by the student volunteers. Every module received superlative ratings compared with other subjects at MIT. The faculty were also enthusiastic and felt it was a superior way to teach. In 1989-90 the courses will be optionally available to all students; the challenge will be to maintain the enthusiasm with a larger class size. In 1990-91 the subjects will be required.

The development of these subjects and the transition between our current curriculum and the new subjects is being supported by curriculum development funds from the School of Engineering. This program is overseen by Professor Herbert H. Sawin and Professor Evans.

GRADUATE EDUCATION

The following table shows graduate enrollment from 1984 - 1989:

	84-85	85-86	86-87	87-88	88-89
Masters	77	72	77	65	54
Doctoral	127	148	151	169	179
TOTAL	204	220	227	234	233

The total for 1988 - 89 includes 76 foreign students, 41 female students, and 9 minority students (not including Asian Americans). The total graduate enrollment has increased over the last several years, even though we are admitting fewer students into the graduate

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program than in the past. This increase is a result of a decrease in the fraction of masters candidates in the program and consequent increase in average residence time.

School of Chemical Engineering Practice

Professor Jefferson W. Tester is stepping down from directing the Practice School Program. Professor T. Alan Hatton will assume the responsibilities as program director working with Professor Jeffrey Feerer who will be the associate program director. Professor Tester, who was promoted to full professor last year, will be directing the Institute's Energy Laboratory as well as maintaining his teaching and research responsibilities in the Department. Professor Hatton, currently the Class of 1922 Associate Professor, will continue teaching at both the undergraduate and graduate level, and will also maintain his research activities in the area of microstructured colloids for bio- and environmental separations and catalysis. Professor Feerer will return to Cambridge after completing three years as the Midland Station Director. In addition to his Practice School duties he will be involved in taking over undergraduate laboratory subjects (10.26 and 10.27) and will be involved with some research at the Energy Laboratory.

This year 40 students participated in the Practice School Program at four stations: Dow Chemical at Midland, Michigan; General Electric at Albany, New York; Syntex Chemicals at Boulder, Colorado; and Chevron at Richmond, California. The Richmond Station is in its first year of operation; the Boulder and Richmond Stations will only be operated during the summer term to accommodate the larger student enrollment. The Midland and Albany Stations will continue year round operation. The Midland Station at Dow Chemical will complete its fourth year of operation this summer with Professor Jeffrey Feerer completing his assignment as Station Director. Professor Feerer worked with Victor Barocas and Gabe Worley as his assistants. The Albany Station, now in its eleventh year of operation, was directed by Professor Greg Mehos with assistance provided by Victor Barocas. During the summer 1989 session, Professor Joel Plawsky, Rensselaer Polytechnic Institute, will join the Albany Station staff to co-direct operations with Professor Mehos. This summer's operation at Syntex Chemicals in Boulder will be directed by Professor Tom Griffin and Kimberly Thompson and at Chevron in Richmond by Visiting Professor Jean P. Leinroth and Rick Holgate.

Fund raising for the Practice School Fellowship endowment continued this year with over \$5.3 million pledged toward our goal of \$8 million.

RESEARCH HIGHLIGHTS

Controlled Drug Release

Incorporating pharmaceutical, agrochemical, or other bioactive agents within solid polymers offers the possibility of not only controlling the rate of release of such agents within very precise limits, but also of sustaining the release for prolonged periods of time. These approaches have profound implications in the treatments of numerous diseases including cancer, diabetes, heart disease, and AIDS. A major program aimed at the synthesis of new biodegradable polymers and of understanding the transport properties of molecules both in polymers and in barriers in the body (e.g. skin, brain) has been developed by Professor Robert Langer and his research group. Specific accomplishments are the creation of the first polymer capable of prolonged release of any molecule greater than 1000 molecular weight, such as polypeptides-molecules being produced by biotechnology; new approaches for externally regulating drug release from polymers involving magnetism, ultrasound, or enzymes; and the creation of several new families of biodegradable polymers. One of these polymer systems is now being used at 16 major US medical centers to treat patients with normally fatal brain cancer.

Plasma Processing

Plasma processes are used in the fabrication of electronic materials to deposit and etch thin films; these are major processes by which microelectronic devices are manufactured. Using a hydrodynamic model to describe the creation, transport, and loss of electrons and ions in rf plasma discharges, Professor Herbert Sawin's research group has demonstrated that the plasma physics of these processes can be predictively modeled. Excellent agreement between the experiment and model has been demonstrated both for macroscopic and for microscopic details (such as optical emission as a function of rf phase and spatial position) indicating that the model describes well the fundamental plasma physics. This research has also led to a technique to characterize the plasma chemistry by using amplitude modulation of the rf power and measurement of the transient optical emission. With this technique, the rate-determining chemical kinetics can be determined in the reactors used in microelectronic processing. For example, it has been demonstrated that CF and CF₂

are lost rapidly by recombination at the electrode surfaces, not by gas-phase processes as had been assumed in the literature for CF_4 discharges.

Separations

As a field of academic study, separation processes has been revitalized over the past few years owing to the increasingly more complex, dilute mixtures of structurally similar compounds and more stringent product purity requirements faced by the biotechnological, environmental, pharmaceutical, and traditional chemical and petrochemical industries. It is these problems that provide the practical and intellectual challenges that make separations a rewarding research area, and that have prompted the group of Professor T. Alan Hatton to explore the use of microstructured colloidal systems to provide the asymmetric environment needed for the sensitive discrimination between solutes exploiting subtle differences in structure and intermolecular interactions. Topics currently under study are solubilization of proteins and other biologicals in reversed micelles, extraction of contaminants from aqueous streams using block copolymers, protein extraction with polyelectrolytes, and chiral recognition in colloidal systems. Experimental approaches range from simple bench top wet chemistry to small angle neutron scattering and NMR studies to provide criteria for the a priori selection and design of colloidal separation agents.

CENTENNIAL CONVOCATION

The Centennial of Chemical Engineering Education, held at MIT the weekend of October 7 and 8, 1989, drew over 800 alumni and other distinguished guests from around the country and the world. Chaired by Professors Clark K. Colton, Robert A. Brown, and James Wei, the Centennial celebration started with a gala reception at the Great Hall at Quincy Marketplace on Friday evening.

Saturday was devoted to symposia at Kresge Auditorium, which explored future directions in research and teaching and examined Chemical Engineering's role in economic prosperity. Featured speakers included Professor John M. Deutch, '61, Provost; Professor James Wei, '54, Department Head; Dr. Ralph Landau, '41, President, Listowel Inc.; Dr. Samuel W. Bodman, '65, President, Cabot Corporation; and Professor Lester C. Thurow, Dean, Sloan School of Management. Other highlights of the meeting included "Personal Reflections on the Early Days," presented by Professors Hoyt C. Hottel, '24, and Herman P. Meissner, '29.

The Open House on Saturday afternoon gave alumni and visitors the opportunities to tour building 66 and to learn about current research activities from displays and demonstrations throughout the building. Over 150 students and numerous faculty members participated as coordinators of displays, tour guides, or general volunteers; and guests were treated to presentations on research currently underway in the department, in areas ranging from combustion to biotechnology.

The Centennial celebration culminated in a reception and dinner dance at the Museum of Science on Saturday night. Professor Wei served as toastmaster, and the featured speaker was Paul E. Gray, '54, President of the Institute. Other speakers included Jennifer Smith, president of the Graduate Student Council; Bernhardt Troudt, president of the Undergraduate Chapter of the AIChE; and Linda Baston, doctoral candidate and alumna of the Practice School. William F. Furter, '55, Dean of Graduate Studies at the Royal Military College of Canada, presented the Department with Eskimo art as a birthday gift from the Canadian Society for Chemical Engineering. Professor Jiading Wang of Tsinghua University in Beijing and Professor Chen C. Ku, '45, of Shanghai Jiao Tong University in Shanghai, read letters of congratulations from their respective universities.

FACULTY

Professor Robert C. Armstrong was appointed Executive Officer of the Department of Chemical Engineering in January 1989.

Professor János M. Beér was the Hoyt C. Hottel Plenary Lecturer of the 22nd International Symposium on Combustion in Seattle, Washington, August 1988. He was awarded the Percy Nicholls Award of the American Society of Mechanical Engineers and the American Institute of Mining, Metallurgical, and Petroleum Engineers "in recognition of outstanding achievement in the field of solid fuels research."

Professor Daniel Blankschtein was the recipient of a 1989 Presidential Young Investigator Award.

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Professor **Howard Brenner** was on sabbatical leave this year at the California Institute of Technology as a Chevron Visiting Professor. He was keynote lecturer at the First Caribbean Conference on Fluid Mechanics held in Trinidad, West Indies in January 1989. He also was appointed to the Editorial Advisory Board of the journal, *Transport in Porous Media*.

Professor **Robert A. Brown** was appointed Department Head beginning January 1989. He was the Stanley Corrsin Memorial Lecturer at the Johns Hopkins University and a keynote speaker at the NATO Workshop on Crystal Growth in Parma, Italy and the Annual Meeting of the Fluid Dynamics Division of the American Physical Society. He spent time this year organizing the new MIT Supercomputer Facility (MITSF) which will operate a Cray-2 supercomputer; he is codirector of the facility, along with Professor Tony Patera of the Department of Mechanical Engineering.

Professor **Charles L. Cooney** received the 1989 Gold Medal for contributions to the field of Biotechnology from the Institute of Biotechnological Studies in London. On the occasion of this award he presented a lecture at the Royal Society in London on the "Evolution of Biochemical Engineering in Biotechnology." He became a regional editor for a new journal *Bioseparations* and was invited as the keynote lecturer at the First Congress of Food and Biotechnologists of Croatia in Yugoslavia.

Professor **Lawrence B. Evans** was the keynote speaker at ASPENWORLD 88, a major international conference on computer-aided process engineering held in Amsterdam in November.

Professor **Jack B. Howard** was the Oblad Lecturer at the University of Utah. In addition, he presented an invited lecture at Göttingen University in West Germany.

Professor **Mark Kramer** was promoted to Associate Professor. He continues to act as Associate Director of LISPE (Laboratory for Intelligent Systems in Process Engineering).

Professor **Robert Langer** was elected to the Institute of Medicine of the National Academy of Sciences. He also received the Founders Award for Outstanding Research from the Controlled Release Society, and was cited for the Outstanding Patent in the State of Massachusetts and one of twenty outstanding patents in the United States. Dr. Langer was named Walter F. Enz Lecturer at the University of Kansas, the Robert Rushmer Lecturer at the University of Washington (Seattle), and the first Presidential Lecturer of the Controlled Release Society (Basil, Switzerland). He also gave the plenary lecture at Diffusion 89 (Parma, Italy) and the keynote speech at the American Chemical Society Meeting on Polymeric Controlled Release (Dallas, Texas). Dr. Langer was elected Chairman of the Gordon Conference on Drug Carriers in Biology and Medicine and elected to the Gordon Conference Research Council.

Professor **Herbert H. Sawin** was promoted to full professor this year. He gave a plenary lecture on the electronic materials processing at the IEEE International Conference on Plasma Science.

Professor **George Stephanopoulos** was the Distinguished ICI Visiting Professor at the University of Newcastle, UK, in November 1988. In April of 1989 he was the Stanley Katz Memorial Lecturer at the City College of New York, and was appointed "Leaders for Manufacturing" Professor of Chemical Engineering at MIT. In addition, he received the Best Paper of the Year Award from *Computers and Chemical Engineering*.

Professor **Daniel I.C. Wang** delivered a Plenary lecture at Biotech '88 in Hannover, West Germany. He was also the Distinguished Lecturer in Biotechnology sponsored by the National Science Council, Republic of China, in 1989. He was given the Outstanding Engineer Award by the University of Maryland, Baltimore County, in 1989. Professor Wang was the recipient of the MIT Graduate Student Council's Teaching Award for the Department of Chemical Engineering in 1989.

Professor **James Wei** concluded his term as President of the American Institute of Chemical Engineers this year. He was a member of the MIT Commission on Productivity, and chaired the panel to study the chemical industry. In addition, he completed eleven years as Department Head.

STUDENTS AND STAFF

Institute-Wide Awards

Sherrill Briese ('90), Karen Fu ('90), Poh Poh Gan ('89), Christine Gundal ('90), Mubasher Humayun ('89), Eleanor Meyer ('90), Ellen O'Connell ('90), Wendy Sanford ('89), Agnes Santosa ('90), and Linda Yeh ('89) were elected to Tau Beta Pi, the Engineering Honorary Fraternity for excellence in academics. Professor Daniel I.C. Wang was selected by the MIT Graduate Student Council to receive the Outstanding Faculty Award for Course X.

Departmental Awards

Agnes Santosa ('90) received the Dow Chemical Outstanding Junior Award, which recognizes achievement in academics, leadership, and campus activities. The MIT Chapter of the AIChE received the Ichthyologists Award for a paper presented by Carlonda Russell at the annual meeting of the New England chapter of the Undergraduate AIChE. The AIChE Annual Chapter Scholarship Award for highest scholarship performance through the first two years was given to Sherrill Briese ('90). The Incentives for Excellence Scholarships Prize in recognition of scholastic excellence by a sophomore or junior was awarded to Evelyn Rabell ('90). The Texaco Philanthropic Foundation Scholarships recognizing excellence in academic performance by students who have completed their junior year in Chemical Engineering were awarded to Karen Fu ('90) and Paul Ouellet ('90). Wendy Sanford ('89) received the Robert T. Haslam Cup for outstanding professional promise in Chemical Engineering. This year's recipient of the American Institute of Chemists Award to outstanding seniors demonstrating leadership, character, and scholarship was Peter Kofinas ('89). The oldest prize in the department, named for Roger DeFriez Hunneman, recognizes outstanding scholarship and research. This year's recipient was Michael Gobler ('89). William Mahoney ('89) and Bernhardt Trout ('89) received the Department of Chemical Engineering Special Service Award for their work as co-presidents of the Student Chapter of the AIChE.

The Dow Teaching Prize, which recognizes excellence in teaching by doctoral students committed to careers in teaching, was awarded to Paul J. Northey and Ronald J. Phillips. The Undergraduate Teaching Assistant Award was awarded to Dimitrios Maroudas. The Rosemary J. Wojtowicz Award for exemplary performance in project work at Practice School was awarded to Linda Baston and David Gray. Special Service Awards were given to Jennifer Smith for her work as President of the Graduate Student Council, and to Robert Kiss for his efforts in coordinating intramural athletic activities.

The Outstanding Employee Award was given to Sonia Foster for exceptional service to the Department. Professor Edward Merrill received the Outstanding Professor Award, presented annually by the Department's Graduate Student Council.

ROBERT A. BROWN

Department of Civil Engineering

Introduction

As noted in the Department's Long Range Plan this year, Civil Engineering is the focal point for the provision of society's diverse needs for construction, infrastructure facilities, and environmental protection; as well as the management of natural resources and the protection from natural and man-made disasters. As "society's engineers," we must provide the facilities that fuel development and economic expansion, and at the same time protect it from potential health, environmental, and safety impacts of that development. To do this, we have had to learn how to hear society's often conflicting needs, consider their multidisciplinary nature, and translate them into a range of sound technological solutions. We have had to learn how to be sensitive to social and economic objectives, communicate the risks, benefits, and costs of these solutions to an amorphous and conflict ridden decision process, and implement the resulting projects. For over 125 years, MIT Civil Engineering has led the profession by providing landmark educational and research programs towards these objectives; evolving as the nature of the problems evolved, and we will continue this heritage of leadership. At the Institute, MIT Civil Engineering, because of its long experience at the interface of science, technology and society, can also provide guidance as MIT seeks to more broadly educate its students for a complex future.

This is a momentous time for the Department of Civil Engineering at MIT. Critical problems of national and international importance that we anticipated during the past five years are now receiving widespread public attention and concern. The position of the Civil Engineer as society's engineer, with its attendant concentration on complexity, large scale systems, and strong interdisciplinary approaches, has led us to develop educational and research programs that are truly relevant to the times. Five years ago we decided to invest in educational, research, and faculty development moves designed to strengthen us in the areas of Infrastructure Rehabilitation and Renewal, Hazardous Substances Management, Advanced Construction Technology, New Materials for Construction, and Intelligent Engineering Systems. Now, five years later, these programs not only vigorously exist but they also make up the mainstay of our activities. In addition to new faculty hires, we have asked existing senior faculty to move to areas more in line with our new Mission - we are now seeing gratifying success in such difficult evolutions.

Undergraduate Education

The Department is now in its third year of operation of a new undergraduate program which features a new more unified specified degree (Course I) which has a sophomore and junior core program. We have also spent considerable time in two undesignated (Course IA) but structured programs in the areas of Environmental Science and Engineering Systems and Computation; all are increasing in popularity, resulting in a steady increase in Civil Engineering undergraduate program enrollment. We have started a request to the Committee on Curriculum to provide a separate degree title for the environmental program as a step towards accreditation, and towards wider visibility at MIT for an undergraduate environmental major. The present program builds on the Department's strengths in fluid mechanics, environmental chemistry and biology, ecology and hydrology, and treatment technology and water resource systems. In addition, it allows students (with faculty guidance) to build programs over an interdisciplinary spectrum, drawing on Chemical and Mechanical Engineering (sources and controls), Toxicology (human health effects), Urban Studies, and Economics and Management (policy aspects).

Subject 1.00 Introduction to Computer Systems is a popular Institute service subject now serving over 400 students per year. It is the largest non-Electrical Engineering/Computer Science computation subject at MIT.

Graduate Programs

The Department has numerous research and educational initiatives at the graduate level. Its educational programs are organized around activities in three divisions: Constructed Facilities, Transportation Systems, and Water Resources and Environmental Engineering. In addition, a cross-cutting Center for Construction Research and

Education (CCRE) has been formed drawing on divisional faculty to address the problems of the construction industry.

Center for Construction Research and Education (CCRE)

The Center for Construction Research and Education has worked hard to build and expand a Ph.D program designed to provide leaders for the construction industry and academia. During this past academic year, five Ph.D degrees were awarded; six previously qualified candidates continued on their thesis research, and nine new candidates were qualified for the program. The Doctoral programs for each has been tailored to meet the student's unique needs and particular professional interests. As a result, twelve of the programs are interdepartmental in nature: five with the School of Management, two with Architecture, two with Electrical Engineering, two with Mechanical Engineering and one with Political Science. We have every expectation that CCRE's Ph.D students will take breadth of vision from the program, and perspectives which we believe are essential to future leadership in industry and in construction and management education.

Constructed Facilities Division (CFD)

Members of the Constructed Facilities Division have joined faculty in Architecture and Mechanical Engineering in a new Building Systems Program. Two actions were pursued to develop a new initiative in the design of Constructed Facilities: Rebuild the academic program with respect to design, and formulate/seek funding for a research program concerned with the design of constructed facilities. The Division significantly expanded the graduate subject offerings by utilizing practitioners to present design aspects for complex structures. The highlight of the year was the Abraham Woolf Lecture Series during which eight outstanding practitioners delivered lectures on a spectrum of design issues ranging from super tall buildings to unique foundation concepts. The second thrust was focused with how to incorporate construction issues in the design process. The Division plans in the near future, to develop a consortium involving firms from both design and construction sectors which would provide the vehicle for dissemination of our research results, and to develop an initiative in non-destructive evaluation of facilities. The aging of our infrastructure is a very serious problem for the United States. Available resources are insufficient to keep up the degradation of the facilities and the most critical need is a technology that would provide accurate information about the condition of a facility. The Division's thrust is focused on developing technologies to assess structures in an accurate yet economical manner. These technologies will require an integration of disciplines such as digital signal processing, geophysics, instrumentation, and mechanics. The Division plans to assemble a research team which will address these concerns and will also plan, in the near future, to develop a graduate academic program in the infrastructure area.

Transportation Systems Division (TSD)

Members of our Transportation Systems Division provide a key role in the educational, research and technology transfer activities of the Center for Transportation Studies (Director, Professor Joseph Sussman, Civil Engineering), and the Center for Technology, Policy and Industrial Development (Professor Daniel Roos, Civil Engineering, is Director of the Center; Professor Richard de Neufville, Civil Engineering, is the Chairman of the Center's Educational Program - the Technology and Policy Program). In addition, TSD makes significant contributions to the Operations Research Center and to the Masters of Science in Technology's Educational Program. The Division continues its major support of the Center for Transportation Studies educational program. Specialty areas include logistics, data management, infrastructure renewal, congestion, transit/rail operations and management, and transportation network design and synthesis. The Division has also taken over leadership for several of our computer-oriented activities: Professor Nigel Wilson is the Instructor in charge of our major Institute initiative, Subject I.00, where he is assisted by Professors Koutsopoulos and Lerman on a rotating basis; Professor Steven Lerman runs our new Intelligent Engineering Systems Laboratory (IESL); and Professor Yosef Sheffi directs our undergraduate Engineering Systems and Computation (ESC) degree program. In the Infrastructure Renewal area, Professors Koutsopoulos and Ben-Akiva work on problems of data acquisition and evaluation for performance assessment of pavements.

Water Resources and Environmental Engineering Division (WREED)

The Ralph M. Parsons Laboratory which houses the Water Resources and Environmental Engineering Division continues to grow and prosper. The Division now has a research budget of over \$4 million/year and is the preeminent group at MIT, and in the nation, for research on the water environment. A project, with the Center for Environmental Health Sciences and MIT Hazardous Substances Group, on contamination in the Woburn, MA area, has come to fruition with three faculty members deeply involved: Professors Sallie Chisholm and Dennis McLaughlin have been funded under a new EPA center in the Hazardous Substances area. Professor Harold Hemond teaches 1.725, one of the four subject sequences in the Chemicals in the Environment series on transportation and transformation chemicals in the environment. The Water Resources and Environmental Engineering Division is a key player in the interdisciplinary Hazardous Substances Management Program, and is providing important guidance to the Institute's efforts in joint activities with the Woods Hole Oceanographic Institute. The Division is also working as part of an Institute initiative in the Global Environment and Climate Change area. The Division hosted three major conferences: Numerical Modeling in Groundwater convened by Professor Michael Celia was held at MIT; Mesoscale Precipitation Conference convened by Professor Rafael Bras was held at MIT; and a Natural hazards Conference was also convened by Professor Bras and held in Perugia, Italy. The Division is now considering an expansion of its activities in the Environmental Science and Engineering area to provide direction and logistics for Institute undergraduates wishing to do an environmental degree.

Program in Advanced Construction Technology (PACT)

Funded as a five-year/multimillion dollar University Research Initiative by the Department of the Army, this Program focuses on basic research and fellowship support for the civil construction industry. During the past year (the third year for the project) the Center was successful in expanding participation (from eight to thirteen) of Departmental faculty and research staff. In addition to eight Departmental faculty, Professor Alexander Pentland of the Media Laboratory, Professor Eric von Hippel of Management, and Professor Carl Peterson of Mechanical Engineering were also involved. The Center for Construction Research and Education (CCRE), which runs the PACT program has made considerable strides in its industrial interactions. In March 1989, the Center presented an Industrial Liaison Program (ILP) Symposium on "Construction in the High-Tech Era" which was attended by over 80 professionals from the design, supplier, and construction sectors of the industry. The Program also attracting considerable outside professional participation in their educational programs. An example was a subject "Failures: A Perspective for Assessing the Design and Construction Process," taught by Dr. Frank J. Heger, an alumnus and former faculty member. Robert W. Page, Assistant Secretary of the Army (Civil Works), and former Chairman and CEO of Kellogg-Rust (at the time the Company was the world's largest engineer/contractor firm), presented the 1989 Henderson Memorial Lecture.

Intelligent Engineering Systems Laboratory (IESL)

This year marked a major breakthrough in funding for the IESL. An Industrial Consortium, headed by NTT Data of Japan, has contributed more than \$1 million/year for the promotion of education and research required to improve, through advances in information sciences and computer technologies, quality and productivity of engineering and construction. Design, construction, and maintenance of constructed facilities is knowledge-intensive and involves extensive communications and coordination among project participants with diverse technical responsibilities. Such work, including conceptual design, setting of interface conditions, conflict recognition and resolution, involves not only characteristics of the product but also knowledge of designer intent and forecasts of the impacts on construction. Current practice does not incorporate the knowledge of constructability in the early design process and often results in extensive renovation. An important linkage made this year has been through interaction with the Media Laboratory and Professor Alexander Pentland. Professor Pentland, a computer visualization specialist, is working with the IESL group on understanding the use of visualization in design and construction. He is also working with Dr. John Williams, of our Research Staff, on a virtual construction software project in which it is possible to test constructability by simulating construction on the computer screen and then used to analyze the performance, scheduling, reliability and cost of the resulting structure. Professor Steven Lerman, who returns to the Department after five years of leadership of Project Athena, is working in the area of Hypertext as a means of managing data and visual images in construction. Other work continues in cooperative engineering design, knowledge

codification, construction robotics, communication and coordination in engineering design, design innovation, geographic information systems, construction planning, infrastructure maintenance, and intelligent computer aided instruction.

Department Administration

Department Head, Professor David H. Marks
Chairman of the Undergraduate Program, Professor Keith Stolzenbach
Undergraduate Research Opportunity Program (UROP) Coordinator, Professor Harold Hemond
Independent Activities Period (IAP) Coordinator, Professor Eduardo Kausel
Chairman of the Graduate Program, Professor Ole Madsen
Admission's Officer, Professor Charles C. Ladd
Coordinator, Student Chapter of ASCE, Professor Lorna Gibson
Coordinator, Chi Epsilon, Civil Engineering Honorary, Dr. John Germaine
Head, Water Resources and Environmental Engineering Division, Professor Rafael Bras
Head, Constructed Facilities Division, Professor Jerome Connor
Head, Transportation Systems Division, Professor Yosef Sheffi
Head, Center for Construction Research and Education, Professor Fred Moavenzadeh
Engineering Internship Program Coordinator, Professor Oral Buyukozturk

Institute Service Roles

The Department continues to play an important role in the leadership of the Institute. Faculty members serving in such roles are: Professor Daniel Roos, Director of the Center for Technology, Policy and Industrial Development; Professor Richard de Neufville, Chairman of the Technology and Policy Program; Professor Frank Perkins, Dean of the Graduate School; Professor Joseph Sussman, Head of the Center for Transportation Studies; Professor Sallie Chisholm, Associate Chairman of the Faculty and Head of the MIT/Woods Hole Program; Professor Herbert Einstein, Head of the REMERGENCE Interdepartmental Experimental Facilities; Professor Fred Moavenzadeh, Head of the Technology and Development Program; Professor W. Kendall Melville, Head of the Joint MIT/Woods Hole Program in Ocean Engineering; and Professor Philip Gschwend, Head of Joint MIT/Woods Hole Program in Chemical Oceanography.

Faculty and Staff

One new faculty member started this past year: Assistant Professor Andrew Whittle joined the faculty in July 1988 in the Constructed Facilities Division. Three resignations were received this past year: Professor Mohsen Baligh, Professor Gregory Baecher, and Professor Michael Celia. Several faculty were on leave: Professor Francois Morel, Professor Herbert Einstein, Professor Daniele Veneziano, and Professor Moshe Ben-Akiva.

Departmental Statistics

Number of faculty: 38 (June 1989) - this is the lowest in some time. We are, several years earlier than the 1992 target; two below the Department's goal to reduce overall faculty by 10% in the School's Program. Number of undergraduates: Fall 1988: 93; expected Fall 1989: 94. Department research expenditure for AY 88-89: \$6.5 million - up from the previous year of \$5.5 million.

Notes About Individual Faculty/Research Staff Members

Dr. Eric Adams (Research Staff) focused his research on field measurements, mathematical modeling and synthesis concerning tidal flushing in estuaries, and has included studies in Boston Harbor (of sewage-derived pollutants), New Bedford Harbor (PCB's from the sediments), Providence River (waste heat from power plants), and Niantic River Connecticut (winter flounder larvae). He has initiated a physical model study of seawater intrusion and purging in the proposed ocean outfall for Boston's new sewage treatment plant, and is continuing his research on cooling lake performance. This past year both he and students have monitored salinity and water quality in the Charles River

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Basin. During Summer, Fall, and Winter, high salinity and low dissolved oxygen levels were found in the bottom layers. The MDC has promised to address problems in the dam locking system and to repair the bubblers used to destratify the basin. He is organizing an International Conference on Physical Modeling of Transport and Dispersion to be held on the MIT campus during August 1990.

Professor Rafael Bras's efforts to formalize interdisciplinary activities in hydrometeorology, hydroclimatology and fluvial geomorphology are coming to fruition. This past summer he hosted a conference in Italy on Natural Disasters in European Mediterranean countries. He also organized and hosted a Conference on Mesoscale Precipitation held at Endicott House last September. A special issue (Vol. 102) of the Journal of Hydrology on: Research in Hydrology: The US-Japan Experience (edited by Professor Bras) appeared in September. Professor Bras's new textbook "Hydrology: An Introduction to Hydrologic Science" will appear by August 1989 (published by Addison-Wesley). He is active in several American Geophysical Union programs and is a member of American Meteorological Society's (AMS) Hydrology Committee. He was appointed to the Advisory Board of the Engineering Directorate at NSF, and became a member of the Atmospheric Sciences and Climate Board of the National Academy of Sciences. He is on the Editorial Board of the Journal of Hydrology and the Board of the Journal of Environmental Technology Research.

Professor Oral Buyukozturk, during Spring 1989, organized the Abraham Woolf Lecture Series on Design of Constructed Facilities (several lectures by outstanding professionals generated much interest in the student community, and each lecture was attended, on average, by approximately fifty participants from MIT and outside). He co-authored three chapters of a book, Mathematical Modeling of Creep and Shrinkage of Concrete, (edited by Z. P. Bazant): Chapter 3: Creep Analysis of Structures; Chapter 4: Finite Element Analysis of Creep and Shrinkage; and Chapter 5: Probabilistic Models. In June 1989 Professor Buyukozturk visited the Technical University of Berlin (TUB) to present several lectures in concrete bridge engineering and to initiate a new direction of MIT/TUB cooperative research bridge engineering. This will include the study of a research bridge under construction for the investigation of different prestressing methods.

Professor Michael Celia is an Associate Editor of the Journal Advances in Water Resources, and is on the Groundwater Committee of the American Geophysical Union (AGU). He co-organized a special session entitled "Pore-scale Models for Multiphase Flow in Porous Media" at the Spring 1989 AGU meeting.

Professor Sallie Chisholm's discovery of a new group of phytoplankton, which are widespread and very abundant in the oceans, was given coverage in the national news media. Last year she became the Director of the MIT/Woods Hole Joint Program, and served as Associate Chair of the faculty. She has published and/or submitted 12 papers during 1988-89.

Professor Jerome J. Connor's efforts during the past year have been focused primarily on initiating activity in Engineering Design with specific research interest in the use of computer based technologies to incorporate reasoning about constructibility issues in the design process. He is also concerned with the development of more efficient structural forms for tall buildings. A new system, the "MIT Concept", which requires considerably less material than the conventional systems has been conceptualized. Preliminary studies indicate a savings in the region of 40 percent of the structural frame cost which will lead to a major advancement in tall building design.

Professor Richard de Neufville has received a Japan Society Fellowship ("Fellowship for Leaders") which will allow him to spend considerable time working and studying in Japan with Japanese academic, business, and governmental leaders.

Professor Peter S. Eagleson received the Robert E. Horton Medal of the American Geophysical Union for "outstanding contributions to the geophysical aspects of hydrology."

Professor Herbert Einstein gave the keynote lecture on landslide risk at the International Symposium on Landslides. He also taught a short course on tunneling on the Colorado School of Mines, gave lectures on tunneling and jointed rock at several universities in Germany, and lectures on landslides at the Norwegian Geotechnical Institute.

Professor Lynn Gelhar has initiated new research funded by the American Petroleum Institute which deals with

field-scale biodegradation mechanisms of dissolved hydrocarbon contaminants in groundwater. He is serving on a panel of experts who are reviewing the waste management program at the Hanford site in Washington for the Department of Energy. Professor Gelhar is a member of the national Research Council's Geophysics Study Committee, which focuses on broad interdisciplinary areas in the geophysical sciences and their link to societal issues. He was an invited speaker at a recent Gordon research conference and presented major new results describing the transport of variable viscosity fluids in heterogeneous porous media; these results have important applications in problems of enhanced oil recovery from oil-bearing rock formations. Professor Gelhar was also an invited speaker at the recent International Symposium on Contaminant Transport in Groundwater in Stuttgart; he presented new results from theory and field experiments demonstrating the important influence of chemical heterogeneity on field-scale dispersive mixing.

Dr. John Germaine (Research Staff) continues his role as a teacher, researcher, and laboratory manager for the Geotechnical Group in the Constructed Facilities Division. He has taken the initiative to develop computer controlled triaxial equipment and state-of-the-art data acquisition hardware and software which has taken a sustained five year effort. As a result, our students are doing much more sophisticated tests, spending more time on interpretation of test results, and looking more closely at material behavior.

Professor Lorna Gibson wrote an invited review paper entitled "Modelling the Mechanical Behaviour of Cellular Materials" for the Journal Materials Science and Engineering. She also was an invited speaker at the First International Conference on Sandwich Constructions held in Stockholm, Sweden June 19-21, 1989. Her work on modelling the mechanical properties of cellular materials continues. The joint project with the Department of Architecture on "Innovative Housing Construction Technology" continues with additional funding from several new industrial sponsors; we are now investigating some promising new materials for roof panels. Professor Gibson began a new collaborative effort on the fracture of cancellous bone in osteoporotic patients with the Harvard Medical School Orthopedics/Biomechanics Laboratory; this project has received funding from the Whittaker Health Sciences Fund.

Professor Philip Gschwend continues his work on the moving of organic contaminants via sorption into colloids in the groundwater; with important new findings about mechanisms for the release of contaminants into the environment, new strategies for sampling groundwater, the calculation of transport retardation of polycyclic aromatic hydrocarbons, many trace metals and radionuclides, and the way we can engineer subsurface deposits to initiate or prohibit colloid mobilization. This work has been presented extensively and is the basis for two EPA "white papers" which provide guidance to the EPA on procedures for superfund site studies.

Professor Donald R. F. Harleman spent a considerable amount of time on an important engineering-public policy issue related to the cleanup of Boston Harbor. This problem is one of a legislated level of treatment versus an overall environmental assessment (water/land/air) of how best to deal with the Harbor problem. He has taken the lead in forming a National Research Council Committee to deal with the generic problem of waste management in urban coastal areas (Boston Harbor will be a case study). In April, Professor Harleman was elected an Honorary Member of the American Society of Civil Engineers (ASCE).

Professor Harold Hemond was awarded this year's Graduate Student Council's Teaching Award. He is continuing his research on an insitu hazardous waste probe, and in field work for hazardous waste problems in the Aberjona River Basin in suburban Boston (Woburn, parts of Wilmington, and several other towns). Research in acid rain watershed geochemistry continues with foci on acid rain effects modeling and hydrologic flow path investigation using new tracer techniques for separating vadose zone flow from saturated zone flow. In the climatic change area, he is doing research on peatland methane evolution, which has a possible feedback effect on climate change. During May Professor Hemond participated in the prestigious Dahlem Conference in Berlin, and is on the Program Committee for an upcoming Chapman Conference on "The Integration of Watershed Chemistry and Hydrology."

Professor Eduardo Kausel has moved steadily towards the direction of Mechanics of Waves. His interest in this field is related to two complimentary research efforts: the uses of wave propagation techniques for infrastructure assessment (i.e., non-destructive testing and remote sensing of civil engineering structures); and the participation in an interdepartmental effort in Structural Acoustics which deals with the propagation and radiation of sound in

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solids and fluids. Professor Kausel was the Department Coordinator for IAP, the Divisional representative of Graduate Admissions, and was elected to become the Chairman of the ASCE's Dynamics Committee.

Professor Steven R. Lerman completed his fifth year as Director of Project Athena. The project was extended for three additional years; however, Professor Lerman elected to turn leadership of the project over to a new director in September 1988, and was granted a sabbatical leave. While on sabbatical he was a Visiting Scientist at Digital Equipment Corporation, participating in the activities of their newly-opened Cambridge Research Laboratory. He worked on a range of projects, including the migration to electronic information delivery on the publishing, libraries and other groups involved in the information industry. He also became Director of the Civil Engineering Department's Intelligent Engineering Systems Laboratory, helping negotiate long term stable funding for that laboratory from NTT Data Systems, Inc. This funding will be the basis for a major set of initiatives within the Department funded by a consortium of companies.

Professor Robert Logcher is Co-Technical Director of the new Intelligent Engineering Systems Laboratory (IESL). He is a member of the ASCE's Structures Division Committee on special structures, and the ASCE Technical Council on Computer Practices Data Base Management.

Professor Ole S. Madsen participated as invited speaker in the 50th Coastal Engineering Research Board Meeting on "Long Range Research Needs in Coastal Engineering" and as co-chairman of the working group on "Small Scale Sediment Transport Mechanics" in the NSF-sponsored "Workshop on Nearshore Processes." Under sponsorship from the Coastal Engineering Research Center, he has initiated a five-year research program on the development of calculation procedures for bottom boundary layer properties and sediment transport mechanics in the coastal environment.

Mr. Carl Martland (Research Staff) is Program Manager of the Association of American Railroads Affiliated Rail Research Program at MIT, and Vice-President of the Transportation Research Forum Foundation. He was Co-Chair of the Transportation Research Forum Regional Conference on "Meeting the Challenge of EDI: A Perspective on the Broader Issues Facing Carriers, Shippers, and Suppliers," held in Boston, June 22-23, 1989.

Professor Dennis McLaughlin has expanded his earlier work in groundwater monitoring. A new project includes the design construction and installation of field instruments while a second deals with real time adaptive monitoring. Joint cooperation with the Hazardous Substances Group and Chemical Engineering has led to a new classroom exercise in hazardous waste cleanup design for use in Chemical and Civil Engineering classes. Professor McLaughlin is also an Associate Editor of Water Resources Research.

Professor Chiang C. Mei is continuing research in the following areas: (1) nonlinear dynamics of ocean surface waves with new emphasis on wind effects and the change of wave spectrum; (2) dynamics of cohesive mud with a view to predicting mud flow in rivers and the silting of estuaries, inlets or harbors; (3) theory for using sound to measure surface waves; and (4) soil consolidation and the theory of homogenization. The last area was initiated in a joint effort with Professor J. L. Auriault of Grenoble, France, where he stayed five months during the start of this sabbatical year. The theoretical technique has potentials for a wide variety of problems such as the mechanics of bubble clouds for which macroscopic constitutive laws are needed from microscopic physics. Professor Mei was keynote speaker at a recent Advanced Workshop for NATO, on Wave Kinematics, in Norway. During this Workshop researchers of wave dynamics conferred with researchers in offshore industry to discuss current status and industry needs.

Professor W. Kendall Melville, in collaboration with Professor Jin Kong of EECS, and Dr. Robert Stewart of JPL/UCSD, participated in a NASA/ONR supported remote sensing experiment from the Chesapeake Light Tower, off Norfolk, Virginia. The results of these experiments will be used to better understand the response of satellite borne instruments to surface waves, and to develop algorithms and theories to parameterize electromagnetic scattering from the ocean surface. International collaboration with the Institut de Mecanique de Grenoble on research into problems of coastal oceanography is continuing with the support of NSF and CNRS. During the year Professor Melville sat on a NASA Earth Observing System (EOS) Review Panel, and was appointed to the Scientific Committee of the IUTAM Symposium on Wave breaking, and the MIT Committee on Curricula.

Professor Fred Moavenzadeh served as a member of the National Research Council's Sub-Committee on International Construction which was established to examine the institutional structure and organization of research transfer and research support related to the construction field. He served as a panel member on the Office of Technology's Assessment Committee to Study Public Works, Infrastructure and Technology. Professor Moavenzadeh was the keynote speaker at the Third International Contractor's Conference in March of 1989 on the topic of "Infrastructure Development and Renewal for the Well-Being of the World." He Chaired the World Economic Forum's Conference Session on Engineering and Construction in April of 1989, and in May of 1989 he was keynote speaker at a seminar at Lehigh University on "Innovative Management Systems for New Construction Technology."

Professor Francois M. Morel has been on sabbatical during 1988-89 and used that time to finish a book ("Surface Complexation Modeling," Wiley Publishers (in press) - with D. Dzombak) and some two dozen book chapters and journal articles now in various stages of publication. He participated in numerous workshops and conferences, including two prestigious Dahlem Konferenzen in Berlin. He also served on an NRC Panel "Research Needs in Anticipation of Future Environmental Problems," and is the Chairman of the Massachusetts Water Resource Authority's Scientific Advisory Panel for Boston Harbor studies.

Professor Daniel Roos has been selected by the Urban Transportation Division of the American Society of Civil Engineers as the recipient of the 1989 Frank M. Masters Transportation Engineering Award.

Professor Yosef Sheffi started a new research program with the Burlington Northern Railroad on pricing of transportation carriers movements. Another research effort looks at the development of object-oriented programming tools for logistics network designs. This effort is an outgrowth of the "ShipSmart and NetSmart" codes for logistics operations developed for the Burlington Railroad last year. A third research direction includes the emergence of third party logistics services providers. Within the Department he continues to serve as head of the Transportation Systems Division and the undergraduate Engineering Systems & Computation programs.

Professor S. Shyam-Sunder presented the 7th Annual Robert R. Gilpin Memorial Lecture at Clarkson University. His talk was on "Constitutive Models for Polycrystalline Ice." His work on ice mechanics has contributed significantly in attracting seven major U.S. oil companies to join a research consortium on Arctic Offshore Engineering. He has also initiated new research concerned with the problem of icing on cables and structures in a search for ways to prevent ice formation on constructed facilities.

Professor Alex Slocum continues work on task identification and design methodology for construction automation; this work included development and proof of concept tests of the Wallbots-robots to install partition wall components. In the precision engineering area, work is continuing on the Atomic Resolution Measuring Machine. Professor Slocum has finished writing, and is now editing, his new book "Precision Machine Design" which will be published by Prentice Hall. Professor Slocum has also received a Royal Society Fellowship and an invitation to be a guest researcher at the Cranfield Institute of Technology's Cranfield Unit for Precision Engineering. Hence, Professor Slocum will be in England for one year beginning October 1, 1989.

Professor Duvvuru Sriram is Co-Technical Director for the Intelligent Engineering Systems Laboratory (IESL). IESL was granted a \$1 million/year grant (which may be extended for three years) from NTT Data, Japan. Professor Sriram has been granted a 1989 Presidential Young Investigator Award from the National Science Foundation in recognition of his contributions to engineering design automation. As a result of his research, the DICE prototype for cooperative engineering design has been successfully completed and a paper will be presented at the sixth ASCE conference on computers in civil engineering. He has also been involved in conducting cognitive studies of actual engineering designs and has formulated a model for the design process. Based on this model, he has initiated projects for the development of computer aided tools for preliminary engineering design.

Professor Keith Stolzenbach continued his work as Co-Chair of the Technical Advisory Committee and Member of the Management Committee for the Massachusetts Bays Program which will sponsor \$1,500,000 of research, over the next two years, on environmental problems in Boston Harbor and Massachusetts and Cape Cod Bays. In a related effort, Professor Stolzenbach initiated a multi-investigator MIT Sea Grant Marine Center project in the area of Coastal Water Quality. This academic year Professor Stolzenbach led the Committee on Admissions and Financial

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Aid in its review of MIT's Admission's Policies and Procedures.

Professor Robert Whitman has led a major research and classroom exercise on the design of an underground parking garage for Post Office Square. Many of the slurry wall construction techniques investigated here will be a major component of the Central Artery project. He is Chair of a National Research Council Committee on the "Estimation of Losses from Earthquakes."

Professor Andrew Whittle joined the faculty in Fall 1988. His main research work during the past year has been in the development of new methodologies for interpreting soil properties from (intrusive) in-situ test devices in clays, sponsored by the Air Force Office of Scientific Research. Professor Whittle has also initiated research in the mechanics of reinforcement of soil masses using new geosynthetic materials. This work which includes both experimental and analytical work is sponsored through the ARO/PACT Center. Professor Whittle has initiated a program of collaborative research on the performance of friction piles in highly overconsolidated clays with Imperial College (London University). He has presented invited lectures to the Boston Society of Civil Engineers and the US Army Corps of Engineers on the design of friction piles in clays. A joint publication on this subject has recently been accepted by the ASCE Journal of Geotechnical Engineering. Professor Whittle was awarded the Doherty Professorship in Ocean Utilization for proposed research on the rate effects in cohesive soils.

Dr. John Williams (Research Staff) has been working on the use of quantitative computer methods in design. He is working with Alex Pentland of the Media Laboratory on virtual construction which combines multi-body dynamics and visualization tools for use in conceptual design. Dr. Williams is Co-Chairman of the Man-Machine Interface Panel at DARPA's workshop on "Concurrent Engineering." Work is also ongoing on construction animation using CAD and image data. The initial project is to improve communication between the diverse parties involved in design.

Professor Nigel Wilson has taken on the job of faculty member in charge of Subject 1.00, our introductory computation subject for the Institute, which is now running 450 students/year. Professor Wilson is Chairman of the Transportation Research Board Committee on Transportation and Performance, and serves on the Editorial Advisory Boards for Transportation Research and the UITP (Union Internationale des Transports Publics) Review.

DAVID H. MARKS

Department of Electrical Engineering and Computer Science

The 1988-89 academic year was an exciting one for the department. It was announced in December that the team of Adler, Corbato and Moses that had led the department for 7 1/2 years would resign on September 1, 1989. A search committee canvassed the entire faculty, and Paul Penfield was chosen as the next Head of the Department. Professor Penfield was Associate Head of the Department from 1974 to 1978. In 1980 he was chosen to head the Microsystems Program, a position he has held ever since. Professor Moses, the present Head, has been appointed Dugald Caleb Jackson Professor, a chair named after the man who led the department for 28 years!

A biannual meeting of the EECS Visiting Committee also occurred in December. Their major concern this time was the length of the SM program, an issue we have discussed before.

Computerization of the department continues. Toward the end of the year thirty Athena workstations were installed in our lab space. They replace the aging DEC 20/60, the first machine we bought for our Educational Computer Facility in 1979 for our software labs. We have also begun a process of supplying Athena workstations to our faculty members who do not already have networked workstations. We began the process with the RLE faculty, and plan to have the rest of the faculty connected in the coming year.

Enrollment in the department continues to decline to about 250 sophomores. The department has, as a result, agreed to accept college transfer students for the first time in about a decade. At this writing we expect a sophomore class next fall that will be close to 240 students.

UNDERGRADUATE PROGRAM

Undergraduate enrollment averaged 900 in 1988-89, with about 60 percent in the Electrical Engineering program and 40 percent in the Computer Science program. The total represents a decrease of about 100 students from the previous year. As a result of a variety of efforts aimed at reducing the number of our undergraduates, 250 sophomores were enrolled in the department this year. This was down from 300 students enrolled in the department the year before.

The following prizes and awards were won by our students:

The Ernst A. Guillemin Prizes for the outstanding SB theses in Electrical Engineering were awarded to Helen Meng of Hong Kong (first prize), and to Suephy Chen of Irvine, CA (second prize). Honorable Mentions went to John W. Murray of Thousand Oaks, CA, and to Christopher Thorman of Great Falls, VA.

The David Adler Memorial Thesis Prizes for undergraduate theses in Electrical Engineering were presented to Colin Angle of Schenectady, NY (first prize), and Paul Sajda of Commack, NY (second prize).

The Charles and Jennifer Johnson Prize for the outstanding undergraduate thesis in Computer Science was presented to George Hu of Renton, WA.

The William A. Martin Memorial Prize for the best thesis in Computer Science was won by Toon-King Wong of Singapore.

The George C. Newton Prize for the best undergraduate laboratory project was awarded jointly to Brian A. LaMacchia of Rockville, MD, and to Deborah A. Wallach of Palo Alto, CA.

A Special Recognition Award was presented by the Department Head to Luis H. Rodriguez for his service to the 6.001 laboratory.

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The David A. Chanen Writing Award, a new prize for the best Computer Science paper used to satisfy the second phase of the Writing Requirement, was awarded to Carl A. Waldspurgen of Norristown, PA.

A new award, the Robert M. Fano UROP Prize, was announced. It will recognize the best work by a Course VI undergraduate in the Undergraduate Research Opportunities Program. This will be awarded for the first time in the spring of 1990.

GRADUATE PROGRAM

In September, 1988, there were 654 graduate students enrolled in the department. Of this number, 200 were newly admitted. About 20 percent of the total were foreign nationals. The department supported 338 Research Assistants and 108 Teaching Assistants. In addition, there were 124 fellowships including 33 National Science Foundation Fellows, 6 Hertz Fellows and 7 ONR Fellows. The remaining students had industrial or foreign support or were using their own funds.

During 1988, the department awarded 172 Master of Science degrees, 17 Electrical Engineers and 59 Doctorates.

The department received 1703 applications for the 1989-90 year, the second year in which the number of applications has decreased. The applicants continue to be generally excellent and 293 were admitted (for February, June and September), of whom we expect approximately 200 to register for next fall.

A number of awards were made to graduate students for excellence in teaching. Salman Ahmad of Pakistan received the Carleton E. Tucker Award and Ted Bloomstein of Highland Park, IL received the Harold L. Hazen Award. Frederick C. Hennie III Awards for excellence in teaching were presented to Charles Selvidge of Belmont, MA, Gregory Wornell of Burnaby, BC, Canada, Anthony Yen of Ft. Lauderdale, FL and Chongwan Lee of Rockville, MD.

Gregory Wornell and Karen Walrath were promoted to Instructor G in recognition of their demonstrated teaching abilities and services to the department.

VI-A INTERNSHIP PROGRAM

In its 71st year, the department's VI-A Internship Program continued its popularity and excellent performance. During the annual selection process the participating companies interviewed 154 sophomore applicants. Although the size of the sophomore class declined by about 50 students, the number of applicants represents a larger percentage of the class than in prior years. Eighty applicants were admitted.

Company participation remained stable with no new companies added this year.

During the year, 66 VI-A students received their Master's and Bachelor's degrees simultaneously, having completed all of their company assignments and their Institute degree requirements. There were also 30 students who were awarded their Bachelor's degrees, most of whom will continue into the graduate phase of the program.

VI-A students continued their excellence in academic achievements as indicated by the following list of awards:

The Carleton E. Tucker Teaching Award to Salman Ahmad.

The Harold L. Hazen Award to Theodore M. Bloomstein.

A Special Recognition Award to Luis H. Rodriguez.

In the School of Engineering two of the three Henry Ford II Scholar Awards went to Jeffrey C. Gealow and Amy W. Lim.

Robert D. Duis and Michael M. Goodwin received Writing Prize awards given by MIT's Writing Program.

Christopher R. Doerr, a double major, received the Admiral Luis de Florez Prize from Course XVI for original thinking.

MICROSYSTEMS RESEARCH CENTER (Professor Paul Penfield, Jr.)

MIT research in microsystems is an interdisciplinary, interdepartmental enterprise that started about 1978, and is coordinated by the Microsystems Research Center. The actual research is carried out in several departmental and interdepartmental laboratories, including the Microsystems Technology Laboratories (MTL), the Submicron Structures Laboratory (SSL), the Research Laboratory of Electronics (RLE), the Artificial Intelligence Laboratory (AI), the Laboratory for Computer Science (LCS), the Laboratory for Information and Decision Systems (LIDS), the Center for Materials Science and Engineering (CMSE), and the Laboratory for Manufacturing and Productivity (LMP).

The technical research areas include electronic materials, submicron structures, integrated-circuit processing and devices, VLSI circuits, design automation, architecture, and VLSI theory. This research is described in other sections of this report by the individual laboratories conducting the research. Coordination activities carried out by MRC include a weekly VLSI seminar series, a unified VLSI memo series, and a VLSI research review each semester. The facilities that enable some of this research are supported in part by the members of the MIT Microsystems Industrial Group (MIG), whose current members include Analog Devices, Incorporated, AT&T, Digital Equipment Corporation, General Motors Corporation, IBM, NCR Corporation, Polaroid Corporation and Raytheon Company.

MICROSYSTEMS TECHNOLOGY LABORATORIES (Professor Dimitri A. Antoniadis)

The Microsystems Technology Laboratories 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 research volume in FY89 was \$5,520,000, up from \$4,115,000 in FY88. The people involved include 16 faculty, 20 research staff, 100 graduate students, 24 undergraduate students, and 17 technical support staff. These faculty and personnel represent affiliations including the Departments of Electrical Engineering and Computer Science, Materials Science and Engineering, Chemical Engineering, Mechanical Engineering, and Physics; the Center for Materials Science and Engineering, the Research Laboratory of Electronics, the Laboratory for Electromagnetic and Electronic Systems, the Laboratory for Information and Decision Systems, the Center for Space Research; the Turbulence Research Laboratory; and the Harvard-MIT Division of Health Sciences and Technology. During the 1988-89 academic year, 12 PhD and 17 SM degrees were awarded in conjunction with this research. The laboratories include three clean room facilities and associated non-clean laboratory space. The centerpiece facility is the Integrated Circuits Laboratory, a state-of-the-art class-10 clean lab with full capabilities for modern IC fabrication. This lab is operated by both full time technical staff and graduate students. This year it achieved "fully qualified" status.

FACULTY

This year six faculty members were granted permanent tenure: Associate Professors Rodney A. Brooks, David K. Gifford, Shafira Goldwasser, Hae-Seung Lee, Martin F. Schlecht, and John N. Tsitsiklis.

Promotions include Assistant Professors William J. Dally and Ramesh S. Patil to Associate Professor; and Associate Professors Jae S. Lim and Roger G. Mark to Professor.

We also welcomed several new faculty members. Srinivas Devadas, Assistant Professor of Electrical Engineering, recently completed a PhD at the University of California, Berkeley. Following a year at Cornell University after receiving his PhD at MIT, David A. McAllester is now Assistant Professor of Computer Science. Martin A. Schmidt received his PhD at MIT and joined the department as Joseph F. and Nancy P. Keithley Career Development Assistant Professor of Electrical Engineering. David L. Tennenhouse received a PhD at the University of Cambridge and is now KDD Career Development Assistant Professor of Computer Science.

We were pleased to have Butler W. Lampson join us as Adjunct Professor of Computer Science. Professor Lampson is one of the nation's leading computer scientists. He has enjoyed a distinguished academic and research career at the University of California and at Xerox, where he was instrumental in helping to develop the personal computer. He is now the chief scientist at Digital Equipment Corporation's new Cambridge research center.

Faculty members received a number of honors and awards this year:

Institute Professor Emeritus Harold E. Edgerton was awarded the National Medal of Technology for his invention of the electronic stroboscopic flash and for finding a multitude of applications for it within science, technology and industry.

Professor Robert G. Gallager was chosen as the first holder of the Fujitsu Professorship of Electrical Engineering. The chair, endowed by Fujitsu Limited of Tokyo, is designed to encourage superior performance by MIT faculty and provide opportunities for creative work and professional development.

Professor John G. Kassakian was elected a Fellow of the IEEE in recognition of his extraordinary contributions to education and research in power electronics.

Assistant Professor Thomas F. Knight was named ITT Career Development Assistant Professor.

The James R. Killian, Jr. Faculty Achievement Award was given this year to Professor Marvin Minsky. The Killian Award recognizes extraordinary professional accomplishments and service to MIT. Professor Minsky was cited as "one of the founding fathers of artificial intelligence" who has "produced a stream of provocative and controversial ideas which have shaped the identity and development of the field." In addition, Professor Minsky was honored with election to the National Academy of Engineering.

Senior Research Scientist Robert Rediker and Professor Henry I. Smith were also elected to the National Academy of Engineering, in recognition of their outstanding professional accomplishments and contributions to the field of engineering.

The Board of Directors of the Engineering Academy of Japan elected Institute Professor Emeritus Walter A. Rosenblith as its foreign associate in recognition of his outstanding leadership in promoting international academic activities and his significant contribution to the establishment of the Academy.

Professor Kenneth N. Stevens was elected a Fellow of the American Academy of Arts and Sciences.

Associate Professor John N. Tsitsiklis was the recipient of the Edgerton Award, presented annually by MIT to an outstanding junior faculty member in recognition of exceptional distinction in teaching, research and scholarship.

Professor Emeritus Joseph Weizenbaum received the 1988 Norbert Wiener Award for Professional and

Social Responsibility. The award recognizes "extraordinary and exemplary practice of the highest standards of social responsibility in the computing field." Professor Weizenbaum was honored for being a "tireless activist for peace in his long career."

Associate Professor Markus Zahn was honored with the department's Graduate Student Council Teaching Award.

Visiting faculty again contributed to, and benefited from, the department's teaching and research activities:

Marija Ilic, Visiting Associate Professor from the University of Illinois, continued to teach an undergraduate subject and to conduct research on power systems with Professor James R. Melcher in the Laboratory for Electromagnetic and Electronic Systems.

Visiting Professor Jacob Katzenelson, from the Technion in Israel, continued his research on computer-aided design tools for electrical engineering with Professor Gerald J. Sussman in the Laboratory for Computer Science, and he also taught an undergraduate subject.

Visiting Associate Professor Nancy G. Leveson came from the University of California, Irvine, to conduct research on safety-critical software development with Professor Barbara Liskov in the Laboratory for Computer Science.

Kameshwar Poolla, Visiting Assistant Professor, came from the University of Illinois to teach an undergraduate subject and to conduct research on multivariable systems and adaptive control with Professor Sanjoy K. Mitter in the Laboratory for Information and Decision Systems.

Several faculty were away this year:

During the fall term, Professor Michael Athans continued work on a text on multivariate control system design.

Associate Professor Robert C. Berwick continued work on a two-volume text on computational linguistics during the fall term.

Professor Leonard A. Gould studied the application of stochastic estimation and identification methods to financial time series at Contravisory Research during the fall term.

Professor Alan J. Grodzinsky continued his research on connective tissue during the fall term.

Institute Professor Hermann A. Haus spent the spring term at Oxford University conducting research on chaos and noise.

Associate Professor Charles E. Leiserson spent the fall term exploring computer architectures at Thinking Machines, Inc.

During the spring term, Professor Sanjoy K. Mitter studied learning in complex systems.

Professor Frederic R. Morgenthaler spent the fall term writing a text on microwave magnetics.

Professor Jerome H. Saltzer spent the spring term at the University of Cambridge exploring new developments and research in the field of computer systems, computer networks, and communications.

Professor Campbell L. Searle conducted research during the academic year into an electronic model for the stimulation of action potentials in nerve fibers.

Books published by faculty this year include Parallel and Distributed Computation by Professor Dimitri P. Bertsekas and Associate Professor John N. Tsitsiklis, published by Prentice-Hall; Made in America: Regaining the Productive Edge by Professor Michael L. Dertouzos, Richard K. Lester, Robert M. Solow, and the members of the MIT Commission on Industrial Productivity, published by MIT Press; and Electromagnetic Fields and Energy by Institute Professor Hermann A. Haus and Stratton Professor James R. Melcher, published by Prentice-Hall.

After a career of ten years as a faculty member in the department, Associate Professor Robert H. Halstead, Jr. has joined the technical staff in Digital Equipment Corporation's Cambridge research center.

We note with sadness the death of Professor Fred C. Schweppe, who died this year at the age of 54. A widely respected authority on large scale electric power systems, Professor Schweppe introduced the concept of network state estimation, which is now an integral part of electric power control systems worldwide. He also developed the Electric Generation Expansion Analysis System, a highly innovative and flexible set of tools to aid the orderly expansion of power networks. The system is now in use in more than 70 major utilities in the US and abroad. Professor Schweppe began his career at MIT in 1959 as a staff engineer at Lincoln Laboratory. His early work there on the control and identification of rocket trajectories led to his eventual opposition to the Strategic Defense Initiative and his abiding concern for technologies applied for human good. He was a Visiting Associate Professor in the department from 1966 - 1968 before becoming a full time member of the faculty in 1968. A prolific writer, Professor Schweppe's latest book, Spot Pricing of Electricity, was published this year. He was elected a Fellow of the IEEE and was an active member of the MIT community throughout his career. His colleagues remember him as generous, supportive, a determined worker and a highly creative individualist.

JOEL MOSES

Department of Materials Science and Engineering

SUMMARY

During the past year, public awareness of the importance of Materials Science and Engineering has continued to grow dramatically. We are witnessing a transition from designing with materials, to design of materials, for a number of critical new technologies. Indeed, many nations hail materials science and engineering as one of three prime technologies for the future, the other two being biotechnology and information technology. Materials advances are increasingly essential to a host of new engineering systems in aerospace, in the ocean, for energy, for the environment, and for consumer products. It is an exciting time to be a materials scientist or materials engineer.

Materials manufacturing has received much emphasis this past year, with approximately 10 percent of our faculty participating actively in the Leaders for Manufacturing Program and others studying how better to produce what they have designed in the laboratory. This new thrust and others have caused us to devote considerable effort in developing revised long-range goals for our Department.

Within our Department, the number of undergraduates remains near our historically highest level, and our graduate program, which has been undergoing a planned decrease in number of students over the past four years, has now stabilized and may grow slightly over the next year or two. Selectivity among our graduate applicants remains very high and we have achieved a much better yield in numbers of students accepting our offers of admission this past year than in recent years. This is in spite of exceptional stipends being offered to the very best candidates by some of our sister institutions. We have been able to maintain our strength or even enhance it, in spite of this strong competition. Nonetheless, the trend of increasing financial competition for the most exceptional students causes some concern for the future.

There have been no new faculty added to our Department this past year, in accordance with the Dean of Engineering's planned ten percent decrease in the size of the Engineering faculty. Now that we have completed this ten percent reduction within our department, and due to the retirement of another ten percent of our faculty over the next two years, we expect to be able to add a number of new faculty in the near future. Professor Edwin L. Thomas, formerly head of the Polymers Program at the University of Massachusetts-Amherst, will be joining our faculty on July 1 of this year. Professor Thomas is an internationally recognized leader in polymer materials science. His presence will greatly strengthen both the Department's and the Institute's efforts in the field of polymer physics.

Our highest priority for gifts and grants is now the development of graduate fellowships, to aid in graduate recruiting. We are pleased to report that the Carl M. Loeb, Jr. Fellowship in Materials Engineering has been established to honor the memory of this outstanding metallurgist. In addition, TECHINT, which is led by Dr. Roberto Rocca ('51), has agreed to support two term fellowships for each of the next three years.

Our IIIB (CO-OP) program continues to attract the vast majority of the undergraduate students in our Department. Through this program we have strengthened our interactions with over twenty-five industrial and governmental laboratories, while providing summer employment experiences for our undergraduates which are relevant to their educational development.

GRADUATE ADMISSIONS AND THE GRADUATE PROGRAM

Our graduate student population as of mid-year was 190, down from 277 students at our all-time high in the fall of 1985. This was a planned reduction to relieve some of the pressures on our faculty to maintaining crowded laboratories and unusually large numbers of research grants. For the near future, we expect the graduate population to grow to slightly over 200. One pleasing change from recent years is that the percentage of applicants who have accepted our offer of admission has risen to 65 percent. This is in spite of the fact that an increasing number of universities are offering our most outstanding applicants stipends which are 50 to 100 percent greater than those which we can provide. Lower stipends, in addition to the high cost of living in the Boston area, place us at a distinct disadvantage with many other outstanding universities. We have been able to hold our own in spite of these difficulties. Nonetheless, we are concerned about these trends in the long term. In order to continue to compete effectively for the very best students, we have placed renewed emphasis on the development of graduate fellowships. These efforts are beginning to show some success.

Approximately thirty percent of our graduate students are women. However, we are beginning to note a trend in which a smaller percentage of the entering women are continuing to the doctorate than are the entering male students. This is also true of domestic male students who are deciding increasingly to stop their education at the master's degree. As a result, our graduate program has an all-time high of forty percent international students, in spite of the fact that the percentage of entering international students has remained at twenty-five to thirty percent. In response to these trends, one of our goals is to develop a professional master's degree, hallmarks of which will be synthesis, complexity, and teamwork, with a possible emphasis on processing and manufacturing. We expect such a program to be attractive to a broader group of domestic students and we hope that this experience will encourage a number of them to continue their studies for the doctorate. We believe that this goal fits directly within the recommendations of the MIT Commission on Productivity and the long-range goals of the School of Engineering.

We are disappointed that the special mailings and brochures which we have sent to minority colleges for the past several years have not produced an increased number of applicants. Nonetheless, we plan to continue our efforts and hope to see an increasing number of such students applying to our Department in the future.

The distribution of our students among our six graduate degree programs, as of February 1989, was:

<u>Degree Program</u>	<u>Percent of Total Graduate Students</u>
Ceramics	17%
Electronic Materials	22%
Materials Engineering	19%
Materials Science	9%
Metallurgy	23%
Polymers	10%

This represents an improved balance in the distribution of students among our various degree programs, as compared with previous years.

During the past year we have had continuing discussions with regard to consolidation of the doctoral qualification program in our Department. We have been striving in recent years, with some success, to obtain extensive overlap in the course content of our six degree programs. One of our long-range goals is to achieve a set of approximately six generic core subjects, each of which would be taken by students in more than one of our six graduate degree programs. Progress has been made in unifying several subjects this past year, most notably in Mechanical Behavior of Materials and in Processing of Materials. This is in addition to existing core graduate subjects in Thermodynamics and Kinetics of Materials. In time, we believe we will have a core graduate program similar in scope to what has been developed over the past ten years at the undergraduate level. We believe that this will strengthen the Department in many ways beyond the benefits to the graduate program itself.

Another major initiative of this past year is the broadening and strengthening of research related to materials manufacturing. Approximately 25 percent of the Leaders for Manufacturing Program fellows are registered in our Department. Professors Kent Bowen, Thomas Eagar and Stuart Brown have been interacting closely with these students and with other faculty from the School of Engineering and the Sloan School of Management. Professor Bowen's and Professor Merton Flemings' work on the Commission on Industrial Productivity, plus the work of a number of other members of our faculty on subcommittees of this commission, have given new interest and new strength to our programs in materials processing and manufacturing. Currently a major research initiative is being developed within the Department with the assistance of faculty from the Materials Processing Center, the Department of Mechanical Engineering, the Department of Chemical Engineering, the Sloan School of Management, and the Laboratory for Manufacturing and Productivity. It is believed that this new initiative will provide a strong manufacturing research complement to the educational programs developed under the Leaders for Manufacturing Program.

PROFESSORSHIPS AND GRANTS TO ENDOWMENT

The continued strengthening of the Department and the broadening of its programs have been made possible to a very great degree by the support of its alumni and of industry. The Department now has seven endowed chairs. One of these, the Morris Cohen Professorship of Materials Science and Engineering, was announced one year ago. The first holder of this Chair

will be Professor Edwin L. Thomas. The other holders of endowed chairs are: H. Kent Bowen, Ford Professor of Engineering; Joel P. Clark, POSCO Professor of Materials Science and Engineering; Merton C. Flemings, Toyota Professor of Materials Processing; and Bernhardt J. Wuensch, TDK Professor of Materials Science and Engineering. We have recently announced that Professor Yet-Ming Chiang will be the new Kyocera Associate Professor of Ceramics. In addition, we are in the process of searching for a junior faculty member to hold the John Chipman Assistant Professorship in Chemical Process Metallurgy.

Term chairs, especially those held by junior faculty members, are of immense value in building their careers. Chairholders and chairs for the coming academic year are: Ronald G. Ballinger, Carl Richard Soderberg Associate Professor of Materials and Nuclear Engineering; Stuart B. Brown, Richard P. Simmons Assistant Professor of Materials Manufacturing; Peggy Cebe, Ester and Harold E. Edgerton Assistant Professor of Polymer Physics; Michael J. Cima, Norton Assistant Professor of Ceramics Processing; Thomas W. Eagar, Leaders for Manufacturing Professor of Materials Engineering; Nicole Herbots, Carl Richard Soderberg Assistant Professor of Electronic Materials; Andreas Mortensen, ALCOA Assistant Professor of Mechanical Metallurgy; Michael F. Rubner, Class of '57 Associate Professor of Polymer Physics; and David A. Rudman, Pirelli Associate Professor of Electronic Materials.

In addition, a generous grant has endowed the Carl. M. Loeb, Jr. ('28) Graduate Fellowship in our Department during this past year. This important gift brings to two the number of endowed graduate fellowships in the Department, expressly intended to aid first year graduate students, and therefore assist us in attracting the highest quality students. We intend to strive for more such fellowships.

FACULTY

Professor Ronald Ballinger, who holds a joint appointment with our Department and the Department of Nuclear Engineering, was promoted to Associate Professor with Tenure. Professor Robert W. Balluffi received the David Adler Lectureship Award of the American Physical Society for his seminal experimental and analytical contributions to materials science. Professor H. Kent Bowen received the University of Utah Alumni Award.

Professor Stuart B. Brown received the 1989 Graduate Student Council Teaching Award in our Department. The Charles S. Barrett Award of the Rocky Mountain Chapter of ASM International, as well as the National Materials Advancement Award given by the Federation of Materials Societies were presented to Professor Morris Cohen for his continuing leadership in our field. In addition, Professor Cohen received an honorary Doctor of Science degree from Northeastern University.

Professor Thomas Eagar, who was appointed Acting Department Head for the second half of this academic year while Professor Flemings is on sabbatical, received a National Science Foundation Creativity Extension Award, and was elected a Fellow of ASM International. Professor Flemings was elected Fellow of The Metallurgical Society, AIME, and Honorary Research Professor of the Institute of Metal Research, Academia Sinica,

Shenyang, China. During his sabbatical beginning in March, 1989, he was Nippon Steel Visiting Professor at the University of Tokyo.

Professor Nicholas J. Grant was elected an honorary member of the Japan Institute of Metals. Professor Linn W. Hobbs has been named a Visiting Fellow of Balliol College in Great Britain. Professor Ronald Latanision has been elected a Fellow of ASM International, and has also been elected President of Alpha Sigma Mu, the ASM honor society. Professor Koichi Masubuchi, who holds a joint appointment in the Department of Ocean Engineering, has been elected a Guest Member of the Japan Welding Society.

Professor Walter S. Owen has been appointed a Visiting Lecturer in the Department of Materials Science of Liverpool University, and was elected an honorary member of the Japan Institute of Metals. Professor Harry Tuller has received special recognition from the Office of Basic Energy Sciences of the Department of Energy for exemplary research, and has also been appointed as a Visiting Professor at the Universite Pierre et Marie Curie in Paris. Professor H. H. Uhlig received the Acheson Award of the Electrochemical Society.

I regret to report that Professor Gregory J. Yurek has tendered his resignation as of August 1 of this year. Professor Yurek has had an active research program in high-temperature oxidation of materials. Recently, he and a number of other faculty helped start American Superconductor Corporation, and he has decided that this new venture will require his full attention.

The Department's teaching and research activities were much strengthened during the past year by the appointment and reappointment of a number of visiting and adjunct faculty. Dr. Lionel C. Kimerling of AT&T Bell Labs continued to teach his graduate course in Compound Semiconductors as an Adjunct Professor in our Department. Dr. Robert A. Laudise, also of AT&T Bell Labs, has continued as an Adjunct Professor and is actively participating in a number of research programs. Both Dr. Kimerling and Dr. Laudise have provided this support to our Department under the sponsorship of AT&T Bell Laboratories. The opportunity to work closely with these two scholars is a significant contribution to our Department.

Visiting Professor Harold D. Brody has continued his work on solidification principles, and is participating in a major effort to grow single crystals of high temperature superconducting oxides. Senior Lecturer David V. Ragone has assisted in teaching kinetics in our undergraduate program as well as working with Professor Joel P. Clark in the Materials Systems Laboratory. Dr. James Livingston of General Electric Research Laboratories, who was a Visiting Professor this past year, will be joining us next year as a Lecturer.

STUDENTS

The Student Undergraduate Materials Society (SUMS) continued to be a significant source of strength and help in the undergraduate program. They conducted mid- and end-of-term subject evaluations, planned socials, and assisted in tutoring of fellow students. SUMS officers during the fall semester were Livia Racz (President), Jamie Wong (Vice President), Elliott

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Schwartz (Treasurer), Ken Battige (Secretary), Shahrnaz Motakef (Academic Chair), and Cindy Shen (Social Committee Chair). New officers, elected in Spring 1989, are: Jamie Wong (President), Ken Battige (Vice President), Rich Wong (Treasurer), and Anahita Jamashidi (Secretary). SUMS has also begun to design the renovation of the Louise Sedlacek undergraduate lounge. Louise Sedlacek ('87) was a graduate of this Department who captured all our hearts and who died a year and a half ago after an extended illness.

Andre A. McFayden was elected to Phi Beta Kappa. Jason M. Lewis and Michael J. Parzuchowski each received awards for the "Best Senior Thesis." Brenda L. Chen, Alison S. Warren and Michael A. Capano received the John Wulff Award for Excellence in Teaching. Olof C. Hellman won the MIT-Japan Science and Technology Prize, and Lloyd H. Hihara received the Uhlig Award of the Boston Chapter of the National Association of Corrosion Engineers. Renu Agrawal and Rob Rosner received the Hoechst-Celanese Award for Excellence in Polymer Science and Engineering.

The Class of 1948 Award, given annually to the male senior athlete of the year, was awarded to Scott Deering (Class of '89), as was the Albert G. Hill Prize for academic excellence and contribution to the quality of life for minorities at MIT. In addition, Scott joined his classmates, Brian Brown and Terry Totemeier (Class of '91), in receiving the Straight T Award for athletic excellence.

Students elected to Tau Beta Pi are: Josephine H. Cheung, Debra S. Miller, Anna P. Napolitano, Patricia L. Obal, Julia C. Putnam, Andrew L. Yee (all Class of '89); and Robert B. Calhoun, Karen T. Ho, Donna S. McCoy, Alice S. Mendelsohn, Dienlan N. Nguyen, Isabel Y. Yang, Michael C. Zody (all Class of '90).

Newly elected members of the Graduate Materials Council (GMC) are: Mary Matthiesen (Chair), Nancy Frier (Vice-Chair), Jimmy Chen (Treasurer), Sossina Haile, Fred Haubensak, and Mark Cox (Social Chairs), Heather Shapiro and Naomi Super (MESS Seminars), Leonard Rubin (Safety Representative), Tami Fletcher (MPC Representative), Jackie Isaacs and Ralph Mason (DCGS Representatives), Mike Warwick and Robin Michnick (GSC Representatives), and Jennifer Lewis (Athletic Chair). GMC continued its seminars and monthly socials including a summer picnic. Graduate course evaluations sponsored by the GMC are being used in the discussion on revision of the General Exam and course content to prevent the need for excessive time in obtaining degrees.

The MIT Student Chapter of the Materials Research Society has the same officers as last year. They are Sergio Ajuria (Chair), Ann Westerheim (Secretary), and Jerry Floro (Treasurer). The group organized a series of lectures on Materials Research in Industry, with speakers discussing opportunities in materials research at their respective companies. In addition, some social activities are being planned for this coming year.

Fellowship awards for one or more semesters were held during academic year 1988-89 by 35 students. These were B. L. Carvalho, Exxon; Shi-Fang Chuang, Foxboro Company; Seng-Shiu Chung, Kevin Coffey, David Dunand, Yachin Liu, and Joyce Wong, IBM; Marlene Spears, Kodak; Craig Garbers, MRRRI; Mark Cox, Raju Rishi, and Leonard Rubin, MPC; Marius Kloppers, Shell; Brian Bennett,

Universal Energy Systems; Pat Cullen, Gillette; Sergio Ajuria, Sossina Haile, Katayun Barmak, Mary Matthiesen, and Arturo Nava, AT&T Bell Labs; Naomi Super, Ida M. Green; Heather Shapiro, Hertz Foundation; Sharon Furcone and Elizabeth Holm, NSF; Chrysanthe Demetry, Jeri Ann Ikeda, Richard Kontra, ONR; Richard Singer, Massachusetts Graduate Grant; Jacqueline Isaacs, Carpenter Technology Scholar; Ralph Mason, N.J. Grant Fellowship; Mark Buonanno, Wyman-Gordon Foundation; James Myers, Simpson Gumpertz & Heger, Inc.; Richard Krueger, Benjamin Samuels, and Julia Schneider, LFM Fellowships.

FACULTY RESEARCH ACTIVITIES

During the past year, Professor Samuel M. Allen completed combined theoretical and experimental studies of structural coarsening in high-strength steels and nickel-base superalloys. In addition, he helped establish a new undergraduate laboratory space for metalworking, ceramics, and glassworking. Professor Benjamin L. Averbach developed a new bearing material for advanced aircraft gas turbines. This material is now being introduced in the newest commercial and military engines. Professor Balluffi has continued his outstanding experimental studies of grain boundary migration. Professor Ronald Ballinger participated as co-leader of the MIT "Cold Fusion" team, giving testimony before the U.S. House of Representatives in April. He has continued to study fracture and corrosion of materials for nuclear energy conversion.

Professor Michael Bever is actively engaged in research and editorial activities in the areas of material substitution, recycling, and waste disposal. Professor H. Kent Bowen is expanding his internationally known work on ceramics processing to deal with the integration of multiple process steps, and to develop broad manufacturing concepts. In addition, Professor Bowen has been a key force in the growth and development of the Leaders for Manufacturing Program in its first year.

Professor Stuart Brown has developed new insights into the mechanisms of weld distortion, while also initiating a new program in the area of powder processing and net shape fabrication. Professor Peggy Cebe has developed a procedure for preparation of the first true single crystals of high performance polymers. This should permit critical property measurements of these new materials in the near future. Professor Yet-Ming Chiang has developed a new liquid-phase reaction-bonding process for synthesizing refractory silicon carbide composites, and has extended his earlier work on oxide superconductor systems.

Professor Michael Cima has developed new understanding of pore formation during thermolysis of green ceramic composites, and has established a large program in processing of high-temperature superconducting oxides. Such work in the superconducting oxides is the key to practical development of these new materials. Professor Joel Clark, as leader of the Material Systems Laboratory, has begun extensive studies of the manufacturing methods and markets for electronic materials. Professor Morris Cohen continues to develop scientific understanding of the tempering behavior of virgin martensites.

Professor Eagar's research on solidification of stainless steels helps explain the seemingly contradictory work of many previous researchers, while his work on gas metal arc welding has shown how to improve productivity by up to 20 percent using this process. Professor John Elliott has been a leader in a two-year national effort to evaluate thermal plasma methods for smelting chromium ores in the hope of developing a domestic ferrochromium industry. He is also deeply involved in a major program aimed at innovative methods of producing steel. Professor Flemings' research on solidification processing was broadened this year to include work on solidification of high-temperature superconductors (with Professors Brody and Cima, and with Dr. Haggerty). Professor Harry Gatos has helped resolve a controversy on the role of vanadium in semi-insulating gallium-arsenide.

Professor Nicholas Grant has helped to organize a major national program involving eight industrial firms, two national laboratories, and his laboratory in research on liquid dynamic compaction for continuously formed sheet and strip alloys. Professor Nicole Herbots has received and is in the process of assembling a major new molecular beam deposition and ion beam deposition system for production of thin films. When completed during this next year, this system, which is partially of her own design, will be unique in its capability of exploring the structure of new materials. It will be utilized by a number of other faculty, including Professors David Rudman and Carl Thompson. She has also developed an important new method for growth of stoichiometric oxides on gallium-arsenide.

Professor Linn Hobbs' work has four major thrusts: high-temperature corrosion, radiation damage of ceramics, structure of glasses, and X-ray diffraction of semiconductors, each of which has progressed significantly during this past year. Professor Keith Johnson has applied his quantum chemical analysis methods both to the high-temperature superconducting oxides and to attempting an explanation of the claimed "cold fusion." Professor Ronald Latanision's research includes a new collaboration with the Microsystems Technology Laboratory on the synthesis of new organic materials for the packaging of electronic, magnetic and optical devices.

Professor Heather Lechtman, in collaboration with Dr. Dorothy Hosler who will assume a new faculty position in the Department of Humanities this next year, has completed a study of the first metallic primitive money system developed in the New World during the prehistoric era. Professor Koichi Masubuchi has continued to extend his studies of residual stress and distortion to provide prediction, sensing and real time control of this significant commercial problem.

Professor Andreas Mortensen has continued work on the infiltration of fiber preforms by liquid metal for the fabrication of metal matrix composite materials. Professor Frederick McGarry has devised a technique to significantly improve the compressive strength of synthetic fibers composed of rigid rod polymers. Professor Walter Owen's work on modeling of interstitial solute strengthening of face-centered-cubic alloys is providing new insights in the design of advanced metals. Professor Regis Pelloux has worked on fatigue crack initiation and crack growth in aluminum alloys and in metallic composites for the next generation plasma fusion Tokamak machines.

Professor Robert Rose has initiated two new research projects on electrochemical modulation and electrosynthesis of high-temperature superconducting oxides. Professor David Roylance has investigated the role of processing variables on the morphology and properties of toughened polyamide resins and the infiltration processing of composites made from this material. In his work on Langmuir-Blodgett thin films, Professor Michael Rubner has constructed a novel organic superlattice of electrically conductive polymers alternating with layers of an insulating molecule. This new molecular architecture provides highly anisotropic electrical conductivities which may be useful in development of new electro-optic materials.

Professor David Rudman has collaborated with many people at the Institute in the area of high-temperature superconductors, but has also made significant progress in fundamental understanding of binary thin film diffusion couples. Professor Kenneth Russell has developed a research program on solidification of monotectic alloy composites in microgravity, while continuing his work on theoretical and experimental studies of wetting of non-metallic fibers by metallic melts for fabrication of metal matrix composites.

Professor Donald Sadoway has developed a non-consumable anode for the Hall cell for production of aluminum which has the potential to save significant amounts of electrical energy throughout the world. Professor Julian Szekely has extended his work on mathematical modeling of materials processing, to development of new processes based upon idealized design of manufacturing systems. This new approach has led to several new patent applications in fields ranging from steelmaking to chemical vapor deposition of electronic materials. Professor Edwin Thomas' work on the role of minimal surfaces in microphase separated structures has received considerable attention for its application to polymer physics.

Professor Carl Thompson's work on electromigration-induced failures in aluminum-based metallic interconnects in integrated circuits has provided a new model of this failure mode which will greatly aid in the development of submicron technologies for future VLSI circuits. In addition, he has developed a new molecular beam deposition methodology for low-defect-density gallium-arsenide films on silicon substrates.

In his research on electrical ceramics, Professor Tuller has demonstrated the ability to vary the oxygen ion conductivity in a continuous manner, from the insulating regime to the intrinsic fast ion conduction mode. Professor John Vander Sande has returned from a sabbatical in which he has helped establish American Superconductor Corporation, a new company which was formed to continue the work that he and others initiated at MIT. A major advance of this past year is development of directional oxidation, a processing routine which he has pioneered and which can lead to highly textured samples with improved properties. Professor August Witt has developed improved methods of characterizing and growing high-purity and high-uniformity gallium-arsenide.

Professor Bernhardt Wuensch is using chemical vapor transport and hydrothermal techniques to prepare unique crystals of a number of new

ceramic materials. Professor Ioannis Yannas has completed an extensive study which shows that the polymeric membrane which he designed performs as well as the natural skin graft in treating burn patients. His studies on regeneration of rats' sciatic nerves by use of copolymer bridges shows that at least 50 percent recovery of nerve function can be accomplished.

RESEARCH STAFF

The research staff of the Department of Materials Science & Engineering plays an important role in helping conduct almost all facets of the Department's activities except formal classroom teaching, and even here they often contribute effectively on an ad hoc basis. During the past academic year, the Department had 69 research staff members among its ranks, in the positions of Senior Research Associate, Principal Research Associate, Research Associate, Post-Doctoral Associate, Sponsored Research Staff Member, and Visiting Scientist.

An additional 15 research staff members appointed through the Materials Processing Center were associated with department faculty. The top two ranks on the research ladder are the positions of Senior Research Associate and Principal Research Associate. These titles are currently held by five individuals who are either appointed through this Department or through a separate laboratory or center, but whose work strongly focuses in this Department. Senior Research Associates are Drs. John S. Haggerty, Jacek Lagowski, and Robert C. O'Handley. Principal Research Associates are James A. Cornie and Paul D. Bristowe.

Dr. Bristowe has made precise X-ray diffraction measurements on the twist grain boundaries of gold which have helped alleviate a controversy concerning the structure of these high-angle boundaries. Dr. Cornie has worked on metal matrix composites in a new pressure casting process with the potential to greatly reduce the cost of fabricating these materials. Dr. Haggerty's current research on the processing and properties of monolithic and composite ceramics has provided silicon-nitride and silicon-carbide compounds with exceptional high-temperature strength. He is also collaborating with a number of faculty on growth of single crystal, high-temperature superconductors.

Dr. Lagowski has provided the first assessment of oxygen impurities in gallium-arsenide. This has been achieved with an international team from MIT, Great Britain and Germany. Dr. O'Handley has succeeded in fabricating the first ferro-magnetic quasicrystal, and has confirmed his previous predictions of unusual properties in these novel materials. He has also had significant success in his efforts to construct the highest resolution scanning electron microscope for magnetic surface imaging. When completed, this will be a unique facility allowing us to probe deeper into the structure of magnetic materials.

THOMAS W. EAGAR

Department of Mechanical Engineering

INTRODUCTION AND PERSPECTIVE

The mechanical engineering profession is broadly concerned with energy, motion and materials, and the design, production, and management of systems to meet the needs of society. The profession will have a central role in addressing the challenges of the next decade relating to the supply and efficient utilization of energy, manufacturing and productivity, safe and efficient transportation, defense, enhancement of the environment, and health care and human rehabilitation. Mechanical engineering practice is changing rapidly due to the increasing capabilities of computation, information processing and measurement control technology, the continued development of the fundamental disciplines, the growing ability to synthesize new materials and processes, and an improved understanding of the life sciences and human factors. These rapid changes provide both significant challenges and opportunities to the profession and for the education of future engineers.

Student interest in mechanical engineering continues to be strong. The Department has the second largest undergraduate enrollment at MIT with a total of 471 undergraduates. Graduate enrollment during the academic year was 387 full-time students, which is consistent with our plan. The demand for students graduating with SB and SM degrees has been strong. The demand for PhD graduates interested in engineering education, particularly in the manufacturing and design areas, continues to be strong as universities respond to the national educational and research needs in these areas.

This past year special emphasis has continued to be placed upon curriculum development. The undergraduate core design and manufacturing subjects have been revised and more closely coordinated to provide an integrated design/ manufacturing sequence. Additionally, a plan to initiate a major study of the overall undergraduate curriculum has been formulated. This study will begin in the summer of 1989. We have also continued to upgrade equipment and instrumentation in the undergraduate manufacturing and materials laboratories.

Faculty effort in identifying and developing research programs in the past year has been notable, particularly in light of the overall national climate. Total sponsored research administered in the Department was approximately \$6.7 million, which is a 3% growth in comparison to the previous year. Research support from industry has continued to be significant, representing approximately 25 percent of the total research administered through the Department.

PROGRAMS OF INSTRUCTION

Objectives

The Department instructional programs strive to educate mechanical engineers for leadership roles in professional practice and engineering education, and to provide a broad flexible background for entering related fields such as medicine, law, management, and public policy. Programs emphasize a basic foundation in the engineering sciences combined with a strong design orientation and extensive laboratory experience which couples theory and analysis with the physical world. At both the undergraduate and graduate levels, involvement of students with faculty in research at the forefront of engineering practice--through special projects, the Undergraduate Research Opportunities Program (UROP) and theses--is a hallmark of the Department.

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UNDERGRADUATE PROGRAMS

Degree Program and Enrollment

The Department undergraduate program leads to the SB in Mechanical Engineering (Course II), which is accredited by the Accreditation Board for Engineering and Technology (ABET) or the SB without specification (Course II-A), which is non-accredited. Course II-B, the Engineering Internship Program, leads to the SB and SM in Mechanical Engineering with thesis research performed at an industrial site.

The Department enrollment continued at levels comparable to the past few years. The new sophomore class of 157 included 22 women and 11 black students. Approximately 32 percent of the class are minorities.

Course II-A provides an alternative to the regular mechanical engineering program for students who wish to design a special program coupling such areas as biomedical engineering, management, and energy policy with mechanical engineering. Thirty-nine students were enrolled in II-A. The Department is heavily involved in the School of Engineering Internship Program with 42 students from the Department participating in the Program: 19 graduate students, 13 seniors, 29 juniors. In 1988-89 the Department awarded 171 SB degrees (135 in Mechanical Engineering, 20 without specification, and 16 in Course II-B).

Undergraduate Curriculum

Significant effort has continued to be devoted to the undergraduate curriculum. During the past year the design and manufacturing undergraduate subjects have been revised, and new equipment including a numerically controlled milling machine and an Instron testing machine have been acquired for the manufacturing and materials laboratories. Additionally, new computational equipment has been installed in an Athena cluster to assist students in the thermal fluid science area as well as in the senior projects laboratory.

The Academic Policy Committee has reviewed the overall curriculum and has formulated a plan for a major curriculum review to be undertaken starting in the summer of 1989. The current curriculum, which was established over fifteen years ago, has served students and faculty well; however, significant changes have occurred in the practice of engineering during the past fifteen years, and the Department will conduct an intensive review of the current curriculum to identify areas that require renewal and the new areas which require development for the next decade. The review of the curriculum will consider the specific knowledge areas in mechanical engineering as well as development of skills relating to oral and written communications, analysis, computation and synthesis, experiences which develop teamwork and a sense of professionalism and ethics in engineering with specific consideration of the role of engineering in society.

New undergraduate subjects developed this past year include: 2.11 Intelligent Systems Design offered in the spring by Professor S. Kim, 2.451J Fundamentals of Energy in Buildings offered in the fall by Professor L. Glicksman, 2.93J Engineers, Scientists, and Public Controversies, a context subject offered in the spring by Professors J. A. Fay, B. T. Feld, and C. Weiner, and 2.94J Accounting for the Social Consequences of Technological Change, a context subject offered in the spring by Professors D. G. Wilson and J. Rothenberg. Additionally, a new context subject was developed by C. Whitbeck, D. Anick, S. Bird, I. Paul, and L. Trilling this academic year which will be offered in fall 1989-90: 2.95J Ethical Issues in the Work Life of Engineers and Scientists.

Undergraduate Student Organizations

The Student Chapter of the American Society of Mechanical Engineers under the leadership of its officers: Wendy Haller, graduate student, President; Vijay V. Vaitheeswaran, Vice-President; Kelly O'Neill, graduate student, Treasurer; and Mark Strong, Secretary; continued to make strong contributions to the Department and professional activities with a membership of nearly 70 students. Professor Igor Paul served as the Faculty Advisor.

Black ME is an organization of black students which provides a supportive environment for minorities in the Department. The membership in Black ME is approximately 25 students. This past year the organization provided academic support in subject reviews, sponsored corporate presentations and had professional engineers make presentations to its membership. Black ME was ably lead by Douglas Cornwall, President; Gregory Markham, Vice-President; Robert Dodd, Secretary; and Andrew Frazier, Treasurer. Professor David Gordon Wilson served as the Faculty Advisor.

Pi Tau Sigma, the mechanical engineering honorary society, continued its strong tradition of fostering student-faculty relations and serving the Department through its course and instructor evaluation program. Activities during the year included chapter meetings, classroom evaluations at mid-term and end-of-term, and a spring banquet to honor newly elected members. The organization was lead by: Rosina Samadani, President; Sue Fatur, graduate student, Vice-President; Christy Alvord, Secretary; and Helen Greiner, Treasurer; with Professor Derek Rowell acting as Chapter Advisor.

Professor Ming-Kai Tse was Faculty Advisor for the Student Chapter of the Society of Manufacturing Engineers which organizes lectures by professionals from industry and industrial plant visits. The chapter officers were: Joe Vorih, graduate student, Chairman; Eugene Tung, graduate student, Vice-Chairman; Barbara Hove, Secretary; and David Wimberly, Treasurer. The chapter membership is approximately 28 students.

Undergraduate Student Awards

Many undergraduates in the Department were recognized for academic and athletic excellence, engineering creativity, and community service.

The Departmental Reinhold Rudenberg Memorial Prize for the outstanding undergraduate thesis in the area of energy was awarded to James D. Worden for his thesis "Solar Powered Land Speed Record Vehicle Design." Also he received a Goodyear Tire and Rubber Co. Award for outstanding work in product design and applications to vehicle systems.

Katherine A. Liliankamp won the Whitelaw Award for original and inspiring design performance in course 2.70 Introduction to Design, while Jennifer L. McKenney won the Whitelaw Award for outstanding design and construction of a robotic manipulator in course 2.70 Introduction to Design.

Deishin Lee and Timothy D. Tuttle won the Departmental Robert L. Hallock Tensile Test Award for outstanding performance in 2.30 Mechanical Behavior of Materials.

Miles Arnone and John E. Massucci won the Departmental AMP award for outstanding performance in course 2.86 Manufacturing Processes Laboratory.

William E. Singhose received the ASME Auxiliary, Inc. Sylvia W. Farny Scholarship Award.

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Several students were recipients of the Departmental De Florez Award for outstanding ingenuity and creative judgment. James D. Worden won first prize for his "Super-Dyno." Second Prize was awarded to David Brancazio for his "Wheelchair Attachment for Ice Skating."

Douglas S. Beck, Aaron G. Flores, Joseph W. Jones, Brian Y. Lim, Michael C. Moldoveanu, Paul H. Moncevicz, Jr., Mark M. Roberts, Randall S. Rowland, Douglas E. Vincent, Robin Prasad, Thomas W. Sacoman, and Andrew L. Yee won the Departmental Wunsch Foundation Silent Hoist and Crane Company awards for outstanding design and fabrication in the Mechanical Engineering area.

The General Motors Scholarship is awarded to second year students in the School of Engineering who excel academically and personally and who have interest in careers in the automotive industry. The Department recipients were John Grooms and Bryon Shaw.

At the 1988 Institute-Wide Awards Convocation Deborah A. Falcone received the Albert G. Hill Prize which is given annually to minority juniors or seniors who have maintained high academic standards or improved the quality of life for minorities, while Yvonne M. Grierson received the Betsy Schumacker Award which is presented annually to an undergraduate woman for excellence in athletic competition. Scott E. Schwartz received the Admiral Edward L. Cochrane Award which is presented annually to a male senior athlete who has shown the highest qualities of humility and leadership, while The Pewter Bowl Award went to Teresa L. Lowenstein for a female athlete for inspiration and leadership. Christina Alvord received a Malcolm G. Kispert award which is presented annually to a female senior scholar-athlete.

Also at the Awards Convocation, Kenneth Goodson received the Louis Sudler Prize in the Arts which is presented to a graduating senior who has demonstrated excellence or the highest standards of proficiency in music, theater, painting, sculpture, design, architecture, or film. The prize is from a fund established by Louis Sudler, arts patron and performer from the Chicago area.

GRADUATE PROGRAMS

Organization

The graduate program is directed by Professors Ain A. Sonin, graduate policy and registration officer, and Triantaphyllos R. Akylas, graduate admissions officer.

Degrees

The Department offers the SM degree in Mechanical Engineering, the undesignated SM degree, the degree of Mechanical Engineer, and the doctorate in Mechanical Engineering. The undesignated SM degree allows students to design special interdisciplinary programs with thesis research performed in the Department, while the Mechanical Engineer program is an alternative to the doctoral program for students who wish to emphasize applications and/or design, including economic and social aspects.

Enrollment and Degrees Granted

Graduate enrollment in the fall of 1988 was 387 full-time students, including 54 women, 10 black, 5 Hispanic, and 13 Asian-American students. In September 1988, 225 new students were admitted from 481 applicants with 146 new students registering.

In 1988-89 the Department awarded 105 SM degrees (of which 19 were combined SB/SM degrees), one Mechanical Engineer degree, and 53 doctoral degrees.

In 1988-89, 88 percent of all graduate students received support from the Department, MIT funds, fellowships, the government, or industry. Seventy percent of the graduate students were supported through research and teaching assistantships.

Graduate Curriculum Development

New graduate subjects developed this academic year which will be offered in 1989-90 include: 2.064 Shear Flow-Structure Interaction (A), by Professor P. Leehey, 2.067J Structural Acoustics (A), by Professors R. Lyon, I. Dyer, A. Baggeroer, 2.280 Fundamentals of Chemically Reacting Flows (A), by Professor Ghoniem, 2.840 Design and Control of High-Precision Machines (A), by Professors A. Slocum and K. Youcef-Toumi, 2.890J Proseminar in Manufacturing, by Professors T. H. Lee and S. C. Graves, and 2.982 Intelligent Control and Sensing of Physical Systems (A) by Professor Asada.

One new textbook was published during the past year: Physicochemical Hydrodynamics, authored by Professor Ronald Probstein, and two additional texts are in process at the printers: "The Principals of Design," authored by Professor Nam Suh and "The Design of Gas-Turbine Engines," written by Professor David Gordon Wilson.

Leaders for Manufacturing Program

A new interdepartmental program was initiated this year--The Leaders for Manufacturing Program. This program is focused on students who wish to enter the field of manufacturing and leads to dual graduate degrees, one in (Mechanical) Engineering and one in Management. Ten students in the Department currently participate in the program. The program fulfills all of the regular degree requirements for the SM in Mechanical Engineering and includes a thesis which is performed working with other students at an industrial site. The Department is playing a major roll in the program with four faculty holding term chairs associated with the program including Professors Timothy Gutowski, David Hardt, John Heywood and Warren Seering.

Graduate Student Awards

Thomas Stahovich was the second recipient of the Warren M. Rohsenow Fellowship. The fellowship was established by alumni to honor Warren M. Rohsenow who served as the graduate registration officer for the Department of Mechanical Engineering for many years.

Norbert Hootsmans was one of the recipients of The Karl Taylor Compton Prizes for students who have made outstanding contributions in promoting high standards of achievement and good citizenship.

Diane M. Brongo and Crispin M. Miller were the recipients of the Carl G. Sontheimer Prize recognizing innovation in Mechanical Engineering.

The Goodyear Tire and Rubber Co. Awards for outstanding work in product design and manufacturing were presented to G. Sean Garrett and John P. Zink for their thesis "A Comparison of Part Alignment Methods for Automated Cleanroom Disk Drive Assembly."

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Robert Fijan received the Whitaker Health Sciences Fellowship, while James Azzola received the Zakhartchenko Fellowship. Nathan Delson and Russell Whipple were recipients of GE Fellowships, while Charles Oppenheimer received the NASA Fellowship, and Fuquan Gao received the Chu Fellowship. James Bobbett and Cheryl Harris were NSF Fellows. Also, Darryll Pines and Frederick Foreman received Patricia Roberts Harris Fellowships.

RESEARCH

Support Level and Distribution

The total volume of sponsored research for 1988-89 administered in the Department was \$6.7 million. Additional sponsored research of an approximately equal amount is administered through interdepartmental laboratories and centers with which Department faculty are affiliated. Department research is supported by a wide spectrum of government agencies and industries. The trend of the last few years of a significant portion of research supported by industry has continued, and approximately 25 percent of the research administered through the Department has been from industry.

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 fraction of faculty involved in the four major Department application areas are: manufacturing, materials and mechanics, 40 percent; energy and environment, 35 percent; biomedical engineering, 25 percent; and systems and design, 20 percent.

Research Accomplishments

Manufacturing, Materials and Mechanics

The major Department activities in manufacturing and processing are associated with the Laboratory for Manufacturing and Productivity (LMP). This interdepartmental laboratory is a focus for research which systematically explores the complex interactions among the many facets of design and production and involves faculty in major program areas of manufacturing automation and robotics, computer-aided design and manufacturing, metals and polymer processing, flexible materials, and tribology.

Significant progress has been made in the robotics area through the research of Professors Neville Hogan, Warren Seering, Jean-Jacques Slotine, Kamal Youcef-Toumi, and Harry West. Development of direct drive motors for robots by Professor Youcef-Toumi, techniques for obstacle avoidance through impedance matching of robot characteristics to the environment by Professor Hogan, improved structural elements for robot arms by Professor Seering, robot control algorithms by Professor Slotine and development of braced manipulator techniques by Professor West have all been encouraging. Research in polymer processing has been performed through the MIT-Industrial Polymer Processing Program by Professor Timothy G. Gutowski in composite materials fabrication. Professor Nam Suh has continued his work to develop design axioms for the manufacturing processes. Professor David E. Hardt has continued research to improve welding processes and metal forming processes through direct application of automatic control techniques. Professor Steven Kim has developed a research program in expert systems for manufacturing using artificial intelligence techniques, while Professor George Chryssolouris has developed a program in intelligent manufacturing. Professor Eli Sachs has initiated a program in the modeling and analysis of electronic materials process equipment. The industrial consortium under the direction of Professor Ernest Rabinowicz and Dr. Nannaji Saka has added several new companies to pursue basic research in tribology related to magnetic recording devices, fuel efficient engines and the mechanisms of friction and wear. Professor Ming-Kai Tse is developing nondestruction

evaluation techniques using tribosensing techniques. The research program in flexible materials conducted by Professor Stanley Backer has developed an improved understanding of the behavior of fibrous rope materials.

In the Mechanics and Materials area, research conducted by Professors Ali Argon, Frank A. McClintock, David Parks, Lallit Anand, Mary C. Boyce, and Rohan Abeyaratne is seeking to develop a better quantitative understanding of the mechanical behavior of materials including inelastic deformation, fracture, and thermo-mechanical coupling effects. Applications of the fundamental analytical techniques and basic experimental studies have been conducted for hot-forming of metals, inelastic response of glassy polymers, development of physically-based models of creep damage, mixed-mode elastic-plastic crack propagation, and interfacial behavior in metal matrix composites. Additionally, in the mechanics area Professor James H. Williams, Jr. is developing nondestructive evaluation techniques for composite materials using acoustic emission techniques.

Energy Generation and Conservation

A number of faculty are directing their research to development of advanced analytical and experimental techniques in energy production and conservation.

Research in the REMERGENCE Laboratory, a laboratory facility developed under the joint auspices of the Mechanical and Civil Engineering Departments, has been conducted by Professor Michael P. Cleary to evaluate rock fracture related to oil and gas extraction and by Professor Peterson to improve mining systems.

In the heat and mass transfer area, Professors Tony Patera and Bora B. Mikic have performed analyses, corroborated by experimental data, which indicate that substantial augmentation of heat transfer rates may be achieved by modulating unsteady flow in channels, while Professor Shahryar Motakef is conducting studies of heat and mass transfer in crystal growth. Experimental studies to characterize two-phase gas-liquid flows associated with power systems have been conducted by Professor Peter Griffith with particular application to emergency cooling of nuclear reactors. New experimental programs to understand multi-component flows have been initiated by Professor Harri Kytomaa for multiphase solid-liquid flows and by Professor John H. Lienhard V to determine heat and mass transfer in two-phase flow systems.

Research in the Sloan Automotive Laboratory, supported by several industrial consortiums, is evaluating the uses of ceramic materials in engines and is developing improved understanding of combustion processes through basic analytical and experimental research. This effort involves Professors John B. Heywood, James C. Keck, Wai K. Cheng, and Ahmed P. Ghoniem and is complemented by basic research in lubrication conducted by Dr. David P. Hault.

Several research programs have been initiated in the Cryogenics Laboratory under the direction of Professor Joseph L. Smith, Jr. and Dr. Yukikazu Iwasa. Major progress has been made in the development of a prototype superconducting generator and in the development of cooling systems for high performance magnets which have application to medical imaging.

A number of fundamental research studies have been conducted this year. Professor James A. Fay has developed basic methods of characterizing the dispersion of gases in the atmosphere with application to acid rain. Research to determine transport of heat and mass transfer across vapor-liquid surfaces in low gravity environments has been conducted by Professor Sonin. Professor Ronald F. Probst and Patricia Renaud have conducted research in the control of ground water at hazardous waste sites.

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Several faculty are developing fundamental computational and analytical tools. Professor Klaus-Jurgen Bathe is developing finite element methods for fluid-structure interactions, while Professor Patera is developing spectral-elements for internal flows, and Professor Ghoniem is developing vortex element methods for turbulent, compressible flows.

A new program in structural acoustics has been initiated by faculty in the Department in cooperation with faculty in Ocean Engineering. Professor Richard Lyon is leading the Department effort with the participation of Professor Triantaphyllos Akylas. Additional research in the acoustic area by Professor Patrick Leehey is determining the noise generated by flows past solid boundaries.

Several faculty have conducted research related to rotating equipment with Professor Stephen H. Crandall developing analytical techniques for evaluation of rotor-bearing support system dynamics and Professor David Wilson developing techniques for turbomachinery design.

Biomedical Engineering

In biomedical engineering research, encouraging progress has been made in areas related to human mobility and sensory aids, treatment of tumors via hyperthermia, development of artificial skin, and development of an understanding of the fluid mechanics related to the cardiovascular, pulmonary, and ocular systems.

In the Eric P. and Evelyn E. Newman Laboratory for Biomechanics and Human Rehabilitation, Professor Robert Mann directed research in which a telemetered hip endoprosthesis was developed providing measurements of pressure in a human hip joint. This data has provided significant insight on the forces generated in hips. Effort to develop aids for the handicapped has continued by Dr. Michael Rosen, while Professor Neville Hogan has continued studies to determine the factors influencing, and the role of feedback, in limb motion. Professor Will Durfee has initiated research in the processing of electromyographic signals for the control of human prostheses. Professor Rowell has initiated the development of a program in medical image processing.

Professor Ioannis Yannas' research to develop and evaluate a biocompatible artificial skin for severely burned patients and materials to regenerate nerves has been encouraging with a number of successful implants conducted in test sites around the country.

In the Laboratory for Medical Ultrasonics, Professor Padmakar Lele and his colleagues have continued research in patient evaluation in which tumors are treated through controlled hyperthermia using focused ultrasound.

Biomedical research in the fluid mechanics laboratory conducted by Professor Roger B. Kamm is directed to developing a basic understanding of the hydrodynamics of ocular solutions in the eye related to diseases such as glaucoma. Professors Ascher Shapiro and Kamm are collaborating on research involving theoretical and analytical studies of the flow in collapsible tubes related to arterial flows. Research by Professor C. Forbes Dewey on identifying the genesis of arteriosclerosis has continued in the experimental quantification of the effects of shear stress on arterial flows, while research by Professor Ernest G. Cravalho has focused on the influence of freezing and thawing of tissues.

Systems and Design Research

In systems and design, research is concentrated in the Man Machine Systems Laboratory, the Computer-Aided Design (CAD) Laboratory, the Vehicle Dynamics Laboratory, the Machine Dynamics Laboratory, the Martin Center for Engineering Design, and the Center for Information-Driven Mechanical Systems.

Professor Thomas B. Sheridan and Dr. Dana R. Yoerger of the Man Machine Systems Laboratory have made significant progress in the development of undersea remote manipulation with the establishment of an experimental test capability to evaluate and modify an undersea manipulator in research coordinated with the Woods Hole Oceanographic Institute.

Professor David C. Gossard in the CAD laboratory is developing expert systems technology and designer-machine interfaces which enhance iterative design functions.

In the machine dynamics area, Professors Steven Dubowsky, Igor Paul, and Harry West have developed a Laboratory simulator to evaluate the dynamic performance of robots' motion on flexible space structures.

The Center for Information-Driven Mechanical Systems was established this last year in the Department under the leadership of Professor Haruhiko Asada. The center will concentrate on the coupling of information processing/computation with mechanical systems. Professors Jean-Jacques Slotine, Thomas Sheridan, and Harry West, as well as a number of other faculty members, are associated with research in the center in the development of intelligent control systems.

In transportation, Professors David N. Wormley and J. Karl Hedrick have continued research relating to automation in the rail industry and to development of dynamic models for evaluation of automotive vehicle safety and performance.

Research to utilize artificial intelligence to aid in engineering design processes has been conducted by Professor Seering, while research on the human computer interface in the design process has been initiated by Professor Mark Jakiela. Professor David Gordon Wilson is leading a group of faculty who are developing innovative uses of video-disk technology in design, while Professor Woodie Flowers and instructor James Grinnell continued efforts to develop visual representations to aid in the design process.

DEVELOPMENT FUNDS

During the last year the Department has benefited significantly from a number of donations and grants given by MIT alumni, friends and industrial organizations. As a part of the Campaign for the Future, the Martin Foundation has endowed a fellowship in the Department to be awarded to a graduate student who is working in the area of design in the Martin Center for Engineering Design, which was established in 1985. This fellowship complements the Warren M. Rohsenow Graduate Fellowship which was established two years ago in the Department by friends and alumni.

During the past year the Collins Junior Faculty Development Chair was established in the Department through generous grants from friends of Professor Collins who was a pioneer in cryogenic engineering and a longtime faculty member in the Department. The Collins Professorship is designated specifically to assist in the development of young faculty who are interested in experimental techniques and in engineering development.

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The Flowers Faculty Development Chair was also established in the Department and will be awarded for the first time in the fall, 1989. The chair was endowed by the Flowers Foundation to support and assist in the development of young faculty.

These two endowed chairs complement the George N. Hatsopoulos Junior Faculty Development Chair which was endowed by Thermo Electron Corp. in 1987 to support young faculty in the Department.

Additionally, the Alcoa Corporation renewed its support of a term development chair in the Department in the area of manufacturing and materials processing.

A number of companies and foundations have continued to provide grants of unrestrictive funds to support faculty and graduate students. These discretionary funds have been used as seed funds to initiate new research areas, to acquire equipment for education and research, and to enhance young faculty development. Grants from Dupont Corporation, Shell Corporation, Exxon, and Procter and Gamble have been of considerable assistance to the Department in the last year.

FACULTY AND STAFF

Size and Composition

On September 1, 1988 there were 61 active faculty: 30 professors, 18 associate professors (16 with tenure), and 13 assistant professors. Seven faculty are minority group members: a black professor, two women, and four Asians. The teaching, research, and technical staff fluctuates at around 65, more than half of whom are part time people whose principal base is either in another department or outside MIT.

New Faculty and Staff

Two new faculty have been appointed to the Department during the last year.

Dr. Haruhiko Asada joined the System and Design Division as a tenured Associate Professor, and Dr. Mark J. Jakiela joined the System and Design Division as an Assistant Professor.

Notable Accomplishments and Awards

Associate Professors David C. Gossard, Neville J. Hogan, and Warren P. Seering were promoted to full professor, effective July 1, 1989.

Assistant Professor Jean-Jacques Slotine and Kamal Youcef-Toumi were promoted to Associate Professor, effective July 1, 1989.

Assistant Professor Shahryar Motakef was promoted to Associate Professor effective July 1, 1989. He also is the first recipient of the Samuel C. Collins Junior Faculty Development Chair, effective July 1, 1989.

Assistant Professor Harry West has been selected as a recipient of the Carl Richard Soderberg Professorship in Power Engineering, effective July 1, 1989.

Professor Ronald F. Probststein received the Ford Professor of Engineering, beginning July 1, 1989.

Professor Steven Kim was selected as a 1989 Presidential Young Investigator by the National Science Foundation.

At the 1988 Institute Awards Convocation, the Graduate Student Council awarded Professor Ain A. Sonin a Teaching Award for "exceptional and inspirational teaching."

Professor Emeritus Warren M. Rohsenow and Professor Stephen H. Crandall are recipients of ASME Honorary Memberships.

Professor Steven Dubowsky and Associate Professor Carl R. Peterson have been named as ASME Fellows.

Professor Ali Argon has been elected a member of the National Academy of Engineering.

Professor John B. Heywood's SAE paper, "A Study of Flame Development and Engine Performance with Breakdown Ignition Systems in a Visualization Engine" was selected to receive a 1988 Arch T. Colwell Merit Award by the Society of Automotive Engineers.

Professor Emeritus Henry M. Paynter gave a Plenary Lecture at the 1989 American Control Conference.

Resignations/Retirements

Three faculty have retired, and two have resigned from the Department, effective June 30, 1989.

Professor Stanley Backer has retired after 38 years at MIT. His association with MIT began with his BS, MS, and Sc.D. degrees. He is Head of the Fibers and Polymers Laboratories, and is a specialist on the mechanical behavior of fibrous materials used in textile and industrial applications. He will continue his sponsored research activities and the supervising of graduate students currently involved in research projects.

Professor James A. Fay has retired after 34 years at MIT. He has received a Fulbright Award for the academic year 1989-90 to lecture in India. He will continue his association with the Department as a senior lecturer.

Professor James C. Keck, Ford Professor of Engineering, has retired after 24 years at MIT. He has been associated with the Sloan Automotive and Reacting Gas Dynamics Laboratories. He will continue his sponsored research activities.

Professor J. Karl Hedrick has resigned from the faculty after 15 years in the Department to accept a position at the University of California, Berkeley.

Associate Professor Ming-Kai Tse has resigned after seven years at MIT. He will continue his association with the Department as a lecturer.

Deaths

Professor Emeritus Jacob P. Den Hartog, at the age of 87, passed away on March 17, 1989, after a long illness. He was an active member of the faculty from 1945 until his retirement in 1967, and served as Head of the Department of Mechanical Engineering from 1954 to 1958. He was known in the Department for his outstanding ability to motivate students, his wit and his vision.

DAVID N. WORMLEY

Department of Nuclear Engineering

Thirty years have passed since the Department of Nuclear Engineering at MIT was first established to provide students with a high standard of education and research in nuclear science and engineering. Over the years alumni have been recognized for their outstanding contributions to nuclear energy and related fields. In particular, three of our alumni received worldwide recognition for their accomplishments during the past year. Navy Commander Frederick Hauck, who headed the space-shuttle *Discovery*, was a featured speaker at the June 1989 Technology Day. The 1988 James McGraw Award to Electric Utilities was presented to William McCormick, Jr. for his "vision and imaginative leadership" in returning Consumers Power to a position of leadership in the community. Last February, Tue Nguyen was awarded the degree of Doctor of Philosophy -- his record-setting seventh MIT degree. With these accomplishments in mind, we look forward to our thirty-first year of educating students who will be capable of assuming the leadership of nuclear energy programs throughout the world.

ACADEMIC PROGRAM

During the academic year 1988-89, the Department welcomed 24 domestic and 18 international students into its graduate program. Of the 150 graduate students registered each term, approximately 40 percent were from the international community. The department's undergraduate enrollment remained constant at, and is expected to continue at approximately the same level.

Advanced degrees were awarded to a total of 42 students at the following degree levels: 13 doctorates, 3 nuclear engineers, 23 master of science, and 3 combined bachelor of science/master of science degrees. Three women were among the degree recipients. In addition to the combined SB/SM degrees mentioned above, three students completed requirements for the bachelor of science degree.

During the year four undergraduate students and two graduate students were affiliated with the Engineering Internship Program. This program, which combines traditional on-campus academic programs with off-campus work experience in industry and government, placed our students at EG&G Idaho and Los Alamos National Laboratory.

In the area of curriculum development, two new subjects were initiated during the past year. Statistical Processes and Atomistic Simulations (22.53) was developed and taught by Professor Sidney Yip during the first semester; it will be offered on a yearly basis. During the spring term, Professor Richard Lester organized a new graduate course 22.843J Technology, Productivity, and Industrial Competition, derived from his service as Executive Director of the MIT Commission on Industrial Productivity. In addition to nuclear engineering, this subject was offered jointly with the Program in Science, Technology and Society, the Sloan School of Management, and the Political Science Department.

The nuclear engineering department (NED) computer committee, consisting of Professors Nathan Siu (chair), Michael Driscoll, Jeffrey Freidberg, and Yip, staff member Rachel Morton, and student Andy Dobrzeniecki, initiated and stimulated a number of actions to improve the use of computers in NED courses. These included the development and presentation of an IAP seminar on software available on NED computers, the acquisition of more modern machines for the department, the introduction of advanced numerical analysis software into a number of courses, and the review of a number of potentially useful software programs (one of which will be adopted by the proposed course on simulation).

Under the direction of Professor Kent Hansen, a new course on computer modelling and simulation (22.44) is scheduled to be offered for the first time next fall. Professors Freidberg, Lawrence Lidsky, Siu, and Yip are also participating in this effort.

An extensive review of the plasma physics and fusion technology curriculum is currently underway. Initial studies indicate that it may be desirable to decrease the frequency with which our advanced courses are offered so as to free up faculty time to teach our core fusion courses 22.601, 22.602, and 22.69.

RESEARCH

During the fiscal year ending June 30, 1988, departmental faculty supervised a research volume of more than \$3 million. This figure includes research funded through the department, the Biotechnology Process Engineering Center, the Energy Laboratory, the Harvard/MIT Division of Health Sciences and Technology, the Materials Processing Center, the Center for Materials Science and Engineering, the Department of Materials Science and Engineering, the Nuclear Reactor Laboratory (NRL), the Plasma Fusion Center (PFC), the Research Laboratory of Electronics, and the Whitaker College of Health Sciences, Technology, and Management.

Research Projects

A major activity of the Nuclear Power Plant Innovation Project was a proposal to the National Science Foundation (NSF) to establish a Center for Advanced Nuclear Power Studies. If funded, this Center will be a significant engineering research facility. Preparation of this proposal was a major undertaking for Professor Michael Golay, involving a commitment of effort for approximately four months. In addition to his nuclear engineering colleagues, he was assisted in this work by faculty from the departments of civil engineering, mechanical engineering, materials science and engineering, and economics. A decision by the NSF is expected later this fall.

Aspects of the innovation project involve study of 1) the light water reactor (LWR), 2) the modular high temperature gas-cooled reactor (MHTGR), 3) the liquid metal reactor (LMR), and 4) institutional and policy analysis. Professors Golay, Elias Gyftopoulos, Mujid Kazimi, David Lanning, Lester, Lidsky, and Neil Todreas have independently and/or jointly continued research in these areas. Professor Golay's research has focused upon methods for design simplification, reduction of human error in nuclear power plant operations and developing a methodology for creation of efficient modular nuclear power plant designs. During the past year this work has been pursued through journal publications, presentations at technical meetings and research with graduate students. The assistance of the Stone and Webster Engineering Corporation is noteworthy.

During the past year construction of an experimental facility was begun under the direction of Professor Kazimi to study the effect of non-condensables on steam condensation under reactor containment conditions. Modelling of the condensation process was initiated for both forced convection and natural convection conditions.

Professors Lanning and Lidsky completed a design study of a direct Brayton cycle turbine power plant based on the passively safe MHTGR core. This study has been widely circulated and has attracted considerable attention. Efforts now have shifted to development of a complete dynamic model to assist in analysis of a candidate control system. The Department of Energy (DOE) has expressed willingness to fund a much larger scale "industrial strength" design study and preparations are underway to begin such an effort.

The DABLE test gas circulator loop has been completed and construction of the primary components has also been completed. The software for the computer-assisted data system is now under development. Under the supervision of Professors Driscoll and Todreas, numerical and analytical work to improve passive decay heat removal by natural convection for advanced reactors such as the MHTGR is continuing.

A DOE program involving 12 faculty principal investigators from five engineering school departments continues its research efforts in the areas of thermal plasmas, fracture mechanics, automated welding, and engineering analysis and design. Professor Hansen is the coordinator of this multi-million dollar, multi-year project.

In-pile loop research into means to achieve dose and corrosion reduction in LWR systems continues at the MIT Reactor (MITR) under the direction of Professors Otto Harling and Driscoll, with strong support by several US utility organizations and increased participation by the Japanese. Professor Ronald Ballinger has initiated, along with Dr. Gordon Kohse of the NRL, a program to study crack growth in stainless steels and electrochemical parameters in-reactor. This program will be funded by the Electric Power Research Institute (EPRI) and Hitachi Ltd.

In the area of nuclear reactor instrumentation and control, Professors Allan Henry, Lanning, and John Meyer, and Dr. John Bernard (of the NRL), along with a group of six to eight students, have been studying the application of fault-tolerant digital systems for instrumentation and automatic control of nuclear power plants. These studies involve research in modelling systems for real-time calculations involved in the control algorithms, as well as simulation and actual reactor demonstration of the fault tolerant concepts for fully automatic control of reactors. The studies include control of small reactor systems such as space power reactors and smaller power reactors combined into multi-modular power reactor systems. Studies are also being made on control of large LWR cores where multi-dimensional effects must be included. A fast running coupled neutronics and thermal hydraulics nodal code has now been made operational. Experiments with the algorithms have been carried out both at the MITR and with a small reactor at the Sandia National Laboratory. Successful tests have now been made over a wide range of power levels and rates of power change in which the unique controller is demonstrated to safely raise the power at a desired rate of change and level the power at the desired valve without overshoot.

In the area of reactor physics modelling, Professor Henry and his students have completed a number of efforts concerned primarily with the fast, accurate prediction of transient behavior. The development of a supernodal method for describing time-dependent neutron behavior in a reactor has been successfully completed. However the method does not appear capable (on a work-station computer) of describing, in real time, transients occurring on the time scale of seconds. To improve this situation a nodal synthesis method has been developed. The scheme looks promising, although it has so far been tested only for static cases. Several codes developed earlier have been improved so that effects due to extraneous sources can now be modelled. Also efficiency has been improved by the use of improved calculational procedures. Finally, further understanding of the most accurate and efficient ways to model transient behavior has been gained.

Research in the development and application of parity simulator concepts has continued with emphasis on the modelling of two-phase flow. Dr. Eduardo Depiante has worked as a post-doctoral research associate with Professor Hansen on this project.

Study in the area of reactor safety, reliability analysis and risk assessment has been conducted by Professors Norman Rasmussen and Siu. Professor Siu continued to work on the

development of methods to treat the impact of dynamically changing process variables on plant risk. A discrete event simulation model that accommodates continuous process variables was developed and applied to simple systems. A project to model the behavior of the plant operator crew during an accident sequence, which complements the above work, was initiated and is well under way.

Efforts in the area of thermal hydraulics and fluid flow have been continued by Professors Kazimi, Golay, and Todreas. Topics such as single-phase multiple channel behavior under decay heat conditions, flow distribution and heat convection mechanisms in bare and wire-wrapped bundles, analysis of heat transfer and hydraulics of two-phase flow, and advanced computational methods for single and two-phase flows are currently under investigation.

Research in the area of nuclear materials and radiation effects continues to be strong. Professors Ballinger and Harling are working on a new and large research effort designed to assess irradiation assisted stress corrosion cracking in LWR structural components. This project represents the first successful efforts to obtain substantial funding for MITR-II based research from foreign sources (Japan). A unique in-pile autoclave with mechanical testing capabilities is a key component of this project. This work has already evoked considerable international interest.

Professor Ballinger's research laboratory has developed an international reputation in the area of fracture mechanics at cryogenic temperatures. His laboratory has participated in an international round robin to develop techniques for J-Integral measurement at cryogenic temperatures. Methods developed in this laboratory are now being implemented by other laboratories.

Professor Kenneth Russell continued his studies on the stability of Fe-Ni-Cr Invar-type alloys, particularly in the presence of intense nuclear radiation. These alloys show a remarkable dimensional stability which makes them very attractive candidates for CTR fusion first wall and fast reactor cladding and duct applications.

NED faculty involved in fusion research include Professors Freidberg, Ian Hutchinson, Kazimi, and Kim Molvig. Professor Freidberg continues his research in fusion towards development of ultra-fast computational techniques for the calculation of MHD equilibrium and plasma transport. Such codes would have wide applicability in the diagnosis of current tokamaks as well as in the design of next generation ignited devices; e.g., Compact Ignition Tokamak (CIT) and International Thermonuclear Experimental Reactor (ITER). Professor Freidberg, Dr. Dan Cohn, and Emmanuel Chaniotakis (a graduate student) are actively investigating ignition and burn control in CIT. They have given several presentations on this work at Princeton Plasma Physics Laboratory.

Professor Hutchinson continues in the role of Division Head for the Alcator C-MOD experiment, the major confinement experiment at the PFC. Construction of this new facility is progressing on schedule. Professor Ballinger has been involved in the materials-related issues concerning this machine. His research group has been active in establishing mechanical performance and in developing materials specifications.

Professor Kazimi's interest in the area of fusion safety focuses on the assessment of design implications of transient thermal behavior of various blanket designs, the chemical kinetics of lithium fires, and of magnetic transients. During the past year he and his students concluded the investigation of the consequences of steam reactions with lithium in fusion designs. They also investigated the consequences of power supply failure on the magnetic coils of the CIT.

The radiation science and technology (RST) area includes research in applied radiation physics, condensed matter science, and radiological science. Professor Yip continues his investigation of fundamental materials properties and behavior through atomistic simulations. This work involves several graduate students and colleagues at MIT, as well as at Argonne National Laboratory, IBM Watson and Almaden Research Centers, and Schlumberger-Doll Research. Financial support has been provided by NSF, IBM, DOE, and ONR-DARPA.

Also during the past year, Professor Yip traveled to the University of Leon, in Leon, Spain, to conduct collaborative research on crack propagation phenomena by computer simulation with former graduate student Benito deCelis. NATO provided a travel grant for this effort. He also received funding from NSF to study the structure and dynamics of amorphous states of matter by molecular simulation.

Professor Sow-Hsin Chen and his student Szu-Li Chang have developed a method of small angle x-ray scattering to directly measure the counter-ion distribution around DNA molecules in solutions. They discovered that the counter-ions in fact penetrate into the major and minor grooves of the double helical DNA. In collaboration with a German group at the Max Planck Institute for Biophysical Chemistry at Gottingen, he has succeeded in measuring the structure of bi-continuous micro-emulsions using small angle neutron scattering techniques.

Professor Gordon Brownell and his research group are currently developing a new positron tomograph, PCR-II. The first such device, PCR-I, has been placed in use for biological study. A proposal entitled "Epithermal Neutron Capture Therapy" has recently been accepted by DOE. Research is expected to begin shortly.

Boron neutron capture therapy for brain cancer has successfully completed its second year with significant progress on all tasks including the design of an epithermal patient treatment beam. Professor Harling supervises research in this area.

Research in the area of waste management has received the attention of Professors Driscoll and Lester. They have directed thesis projects dealing with several aspects of high-level waste disposal, including the consequences of further delay in construction of a repository, and the waste disposal characteristics of advanced reactor fuel cycles.

In the area of nuclear-powered submarines in non-nuclear weapons states, an international conference which considered both the technical and the geopolitical aspects of the subject was held in March 1989 at MIT. The meeting was organized and chaired by Dr. Marvin Miller, and cosponsored by our department and the Defense and Arms Control Studies Program (DACs) at MIT. Professor Lanning and graduate student Thomas Ippolito presented a paper on some technical aspects of the use of low-enriched vs. high-enriched uranium fuel in submarine reactors.

New Research Projects

A study has been initiated in the area of space nuclear power systems. Professor Lanning is working with a graduate student and one or two UROP students on the assessment of possible nuclear power systems for deployment in stations such as a lunar station. The specific reactor under assessment is the Space-Thermionic Advanced Reactor Compact called the STAR-C reactor. Possible design concept studies and reactor control studies have been initiated.

Professor Hansen and Dr. Tatsujiro Suzuki of the MIT Energy Laboratory are analyzing and comparing the nuclear safety regulatory systems in Japan and the US. The Stone and Webster Engineering Corporation's grant to the Department has been used to support Ken Meyer, a graduate student in the TPP program, in a research project investigating the potential use of information science tools in nuclear plant service and maintenance.

With support from the American Academy of Arts and Sciences, Dr. Miller initiated a new research project on nuclear proliferation in the Middle East with Dr. Avner Cohen of Tel-Aviv University in Israel. Dr. Miller traveled to Israel in March 1989 for discussions on the subject with government officials, academics and journalists.

Professor Yip received a 3-year NSF grant to study, in collaboration with Professor S. Shyam Sunder of the Civil Engineering Department, the structure and mechanical properties of ice formed on various substrates.

FACULTY ACTIVITIES

Nuclear engineering department faculty members have been actively involved in numerous on-campus activities throughout the year. A sampling of these activities is listed below.

In September 1988, Professor Kazimi was host to two scientists from the Kurchator Institute in Moscow. Dr. Alexander Kashirskiy and Dr. Victor Kapyshev's three-week visit to MIT was organized under the bilateral cooperative agreement with the Soviet Union in the area of fusion research and development.

Professor Yip organized an informal faculty seminar series, the "Brunel Seminars," during the spring term. During the summer of 1988, special summer sessions were offered by several faculty. Professors Rasmussen and Todreas presented their annual two-week course entitled, "Nuclear Power Reactor Safety." This session continues to be well attended by members of the US industry as well as those of the international community. Professor Henry again presented a week-long course on "Modern Nodal Methods for Analyzing Light-Water Reactors." This summer presentation continues to be a very popular offering.

Departmental administrative responsibilities were ably handled by the following faculty during the academic year 1988-89. Professor Freidberg continued as the Graduate Admissions Officer and Professor Kazimi as the Financial Aid Officer. In anticipation of his appointment as Department Head effective July 1, Professor Kazimi turned over the financial aid assignment to Professor Lanning on June 1. Professor Driscoll, who plans to retire next fall, completes his term as Recruiting Officer on June 30; Professor Golay will assume this position for the coming academic year. Professor Henry served as the Department representative on the Committee on Graduate School Policy (CGSP).

The department's doctoral qualifying exams were coordinated by Professor Molvig. Professor Meyer, who chaired the Committee on Undergraduate Students, also served as the faculty advisor for the honorary Alpha Nu Sigma Society. In addition, he led the preparation of the department's questionnaire that will form the basis for re-accreditation action during the coming school year. Besides serving on the computer committee, Professor Siu was the faculty advisor for the American Nuclear Society (ANS) Student Chapter. He also coordinated the department's Independent Activities Period (IAP). Professor Ballinger continued to supervise the UROP program, the Engineering Internship Program, and also served as the Undergraduate Financial Aid Officer. Professors Brownell, Freidberg, Gyftopoulos, Lester, and Rasmussen, the department's

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Graduate Registration Officers, assisted the students during the academic year. Professor Todreas served in this capacity during the summer term. He also chaired the department's Safety Committee.

In addition to departmental assignments, our faculty have made significant contributions to both School of Engineering and Institute activities throughout the year.

Professor Lester continued his appointment as Executive Director of the MIT Commission on Industrial Productivity. The Commission, consisting of 16 leading social scientists, engineers, and physical scientists on the Institute faculty, was charged with the task of analyzing the causes of productivity weakness in US industry and developing recommendations, particularly regarding education and research, in support of the national goal of strong, sustained productivity growth. The Commission's final report, *Made in America: Regaining the Productive Edge*, by Michael L. Dertouzos, Richard K. Lester, Robert M. Solow, et al., was published by the MIT Press in May and has attracted widespread interest. As a result, Professor Lester has participated in an extensive series of presentations of the Commission's findings before numerous industrial, Congressional, Executive Branch, and academic groups in the US and overseas. He also serves on the Program Board of the Center for Energy Policy Research and the faculty advisory board of the Center for Technology, Policy and Industrial Development.

Professor Yip was invited to be a House Fellow of Ashdown House. He also began serving as a member of the Athletic Board. Professor Gyftopoulos continued his services as Faculty Chairman of the MIT Sustaining Fellows Program, as a member of the Review Group on Context Subjects, and as a member of the advisory committee of the Center for Advanced Engineering Study.

Besides serving as departmental CGSP representative, Professor Henry holds membership on the Institute's Advisory Committee on Shareholder Responsibility. Professor Lidsky completed his term as chair of the Institute's Committee on Curricula; he also serves as a member of the Review Group on Context Subjects. Professor Molvig continues on the Faculty Club Advisory Board.

The Committee on Outside Professional Activities is chaired by Professor Golay. Professor Todreas is also a member of this committee. Professor Todreas chairs the Committee on Radiation Exposure to Human Subjects and both he and Professor Rasmussen are members of the Institute Council of Environmental Health and Safety.

Professor Rasmussen continues to serve as chairman of the Committee on Reactor Safeguard. He is assisted on this committee by colleagues, Professors Ballinger, Harling, Kazimi, and Lanning. Professor Harling also directs the NRL, an interdepartmental facility.

Nuclear engineering faculty have continued to expand their professional horizon by their involvement in off-campus professional conferences and speaking engagements. Professor Hutchinson visited the People's Republic of China under the auspices of the US Department of Energy to participate in a review of Chinese research activities in controlled fusion. The US is implementing a program of international collaboration with China.

During 1988 Professor Golay was actively presenting the results of work on the reactor innovation project. Such presentations included lectures and visits to industrial firms and research installations in Taiwan, Japan, Korea, France, West Germany, and Italy.

Professor Lidsky was invited to an international workshop on greenhouse phenomena held in Aachen, Germany. At this workshop the possible impact of second generation nuclear

systems on atmospheric burdens was discussed. In conjunction with this workshop, Professor Lidsky also presented invited papers at KFA in the Federal Republic of Germany and at Framatome in France. The environmental impact of second generation nuclear systems was also discussed at a meeting of the Edison Electric Institute.

Dr. Miller renewed his activities -- begun in the early 1980's with the late David Rose -- on the energy policy implications of greenhouse warming. Dr. Miller gave two talks on this subject in May 1989 at a meeting of the International Motor Vehicle Program in Acapulco, Mexico, and at an ILP-sponsored symposium at MIT.

During December and January 1989, Dr. Miller traveled to India and Pakistan with George Rathjens, Professor of Political Science, for discussions on nuclear power and proliferation. While in Bombay, Dr. Miller gave a talk on this subject at the Bhabha Atomic Research Center. He also continued his collaboration with a group of US and Soviet scientists in the area of arms control. He is a co-author of a paper on detecting nuclear weapons which will appear both in book form and in a new journal, *Science and Global Security*.

In October 1988, Professor Gyftopoulos participated in an international conference on Biopolitics in Athens, Greece. At the conference he presented a paper entitled, "In Praise of Technology's Humanity." This month he was the keynote speaker at an international symposium on Thermodynamic Analysis and Improvement of Energy Systems, held in Beijing, China.

In November 1988, Professor Todreas was a keynote speaker at the Third International Meeting on Reactor Thermal Hydraulics and Operations, held in Seoul, Korea. The title of his talk was "Nuclear Reactor Thermal Hydraulic Research, Why Can't We Do It Better?" Professor Kazimi also presented an invited lecture at this conference entitled "Recent Developments in Thermal Hydraulics of Severe Accidents." Last month Professor Kazimi also served on the Steering Committee of the seminar on fission product transport in severe accidents which was held at the International Center for Heat and Mass Transfer in Dobrovnic, Yugoslavia.

Professor Chen was a major invited speaker in a NATO Advanced Study Institute "Hydrogen-Bonded Liquids" held in Cargese, Corsica, France, during the month of April.

Professor Harling organized and chaired an international workshop on epithermal beam development for neutron capture therapy. The 20 invited and 6 contributed papers are being published in a special volume. He also acted as a reviewer for DOE's new program in support of academic research in nuclear engineering. In addition, he continued to represent the entire US university research reactor community in efforts to obtain a rational base of funding from the federal government. In the spring he gave testimony before two subcommittees of the US Congress on this matter.

Professor Ballinger has participated as co-leader of the MIT "Cold Fusion" team. In this capacity he testified before the US House of Representatives Committee on Science, Space, and Technology last April.

Also during the past year, Professor Freidberg was asked to give talks at Cornell University and the Courant Institute at New York University concerning a novel approach to the understanding of ignition physics and burn control in tokamaks. In May, Professor Molvig was invited to give the Magneto-Fluid Dynamics Seminar which was also hosted by the Courant Institute.

Dr. Miller gave seminars on the subject of nuclear-powered submarines in non-nuclear weapons states at Princeton University, the University of Montreal, and the Oak Ridge and Brookhaven National Laboratories. In December, he presented an invited paper on tritium verification and safeguards at a symposium on the tritium factor in arms control at the American Academy of Arts and Sciences in Cambridge.

At its July meeting, Professor Kazimi presented an invited lecture entitled "Fusion and the Environment" at the Radioactivity and the Environment Meeting of the American Nuclear Society. Professor Henry presented papers at ANS meetings held in Jackson and Santa Fe. Professor Siu participated as a member of the Technical Program Committee for PSA'89, the ANS's International Topical Meeting on Probability, Reliability and Safety Assessment. He also chaired a session at that meeting.

Professor Russell organized and chaired a TMS-AIME conference on "The Physical Metallurgy of Invar Alloys" and is senior editor on the upcoming symposium proceedings of the same name. In December, Professor Golay presented the paper, "International Directions in Advanced Nuclear Reactor Development" at the invitation of the Climate Institute at their annual meeting in Washington, DC.

In addition to participation in professional conferences and seminars, department faculty are well represented in professional associations. Professor Rasmussen was appointed to the Presidential Commission on Catastrophic Nuclear Accidents. He also reviewed nuclear safety aspects of NASA's Galileo mission for the President's Science Advisor. He is a member of the committee on film badge dosimetry of the National Research Council; a member of the Visiting Committee of Princeton Plasma Physics Laboratory, Brookhaven's Department of Nuclear Energy, and the Los Alamos Scientific Laboratory. He also serves on the safety review committee to Savannah River Laboratory and Rocky Flats Laboratory.

Professor Lester was appointed to the Board on Radioactive Waste Management of the National Academy of Sciences, and also to the National Research Council's Committee on Future Nuclear Power Development. Professor Kazimi served on the planning group for severe accident safety research at the Nuclear Regulatory Commission. He was elected to the Executive Committee of the Thermal Hydraulic Division of the American Nuclear Society for a three-year term, 1988-1991.

Professor Molvig chaired the DOE's Magnetic Fusion Advisory Committee Panel 22. After completing an extensive and intensive review of magnetic fusion facilities, the Panel submitted their findings and recommendations to the DOE. Earlier this month, Professor Molvig appeared before a Senate Subcommittee on Energy and Natural Resources to give testimony regarding the DOE magnetic fusion program.

Professor Hansen continues to serve as a Director of Stone & Webster Engineering Corporation. He is on the Scientific Advisory Committee to the Idaho National Engineering Laboratory and continues as a member of the National Research Council's Commission of Engineering and Technical Systems.

Professor Lanning continues to serve on the Safety Audit Committee at Northern States Power Company. He served on a committee to review the design aspects of the Advance Neutron Source, a high powered research reactor concept proposed by DOE for future neutron related research. During the past year, Professors Lanning and Todreas completed their service on the National Academy of Sciences/National Research Council's Committee to Assess Safety and Technical Issues at DOE Reactors.

Professor Todreas chairs the Nuclear Safety Research Review Committee of the Nuclear Regulatory Commission. He also serves on the review committee of the Reactor Analysis and Safety Division at Argonne National Laboratory. Professor Chen was appointed to the Intense Pulse Neutron Sources review committee for both the Argonne National Laboratory and the Los Alamos National Laboratory.

Professor Driscoll chairs the review committee for the Applied Physics Division at Argonne National Laboratory. Professor Freidberg is serving as a member of the review committee for computer applications in the magnetic fusion energy program. He also served as chairman of the five-year review committee for the Institute for Fusion Studies at the University of Texas at Austin. This year he completed his two-year term as a member of the national fusion Sherwood Theory Executive Committee.

Professor Meyer is a member of the Technical Program Group for the Savannah River Laboratory Limits and Uncertainty Program. He also served on a review committee for the Nuclear Engineering Department at the University of Michigan. Professor Henry is a member of the Program Committee for the International Conference on the Physics of Reactors to be held in Marseille, next April.

Professor Henry is a member of the Editorial Advisory Board for *Nuclear Science and Engineering*. Professor Todreas continues to serve on the editorial board of the *Journal of Nuclear Engineering and Design*; he also joined the boards of *Nuclear Science and Engineering* and the *International Journal of Heat and Fluid Flow*.

Honors and Awards

During the past year members of the faculty and staff recognized for their contributions to the field of nuclear energy included Professors Rasmussen, Hutchinson, Freidberg, and Todreas, and Dr. Bernard. The Nuclear Reactor Safety Division of the American Nuclear Society presented the George Laurence Award to Professor Rasmussen. This distinguished award is given to an individual for his "pioneering leadership in the field of reactor safety."

Professor Hutchinson was elected a Fellow of the American Physical Society. Dr. Bernard, Director of Reactor Operations at the NRL, received the ANS's "Young Member Engineering Achievement Award" this year. This award recognizes Dr. Bernard's pioneering work in the field of computer control of reactors. The Graduate Student Council's Outstanding Teacher Award for 1988-89 was presented to Professor Freidberg.

Professor Todreas and Dr. Victor Iannello received the Best Paper Award for 1988 from the Thermal Hydraulics Division of the ANS. This paper, which reported the results of Dr. Iannello's PhD thesis research, was titled "Mixed Convection in Parallel Channels with Application to the Liquid Metal Reactor Concept."

Professor Ballinger received a patent for the development of Incoloy 908. This is a new high strength low coefficient of expansion alloy for cryogenic structural applications.

Retirement

Professor Driscoll has announced his plans to retire in October 1989 to permit increased attention to his research commitments and to make more time available for other scholarly pursuits.

STUDENT ACTIVITIES

The MIT Student Chapter of the American Nuclear Society completed another outstanding year of service and support to their fellow students, faculty and staff. For the Monday afternoon seminar series, they arranged for guest lecturers from the utilities, industry, and education so that a wide range of topics were presented. They also continued the tradition of student/faculty pizza meetings, a holiday party, and a departmental steak cookout. They organized the department's orientation activities, provided student speakers for high school groups, and participated in intramural sporting events.

The Alpha Nu Sigma honor society updated and distributed a booklet, "Student Guide to the Nuclear Engineering Department," which provides students with useful information on all aspects of the department. Ten new student members (three undergraduate and seven graduate students) were inducted at the annual banquet this spring.

Honors and Awards

Scott Peng completed his term as president of the MIT Graduate Student Council. As president, he was actively involved on various faculty and administrative committees.

The announcement of graduate fellowships for the coming academic year was made at the April student/faculty meeting. The Manson Benedict Fellowship for 1989-90 will go to Olivier Herbelot, a graduate student working in the area of fusion. Erol Cubukcu will receive the Theos Thompson Memorial Fellowship. Mr. Cubukcu is interested in fission-related research.

Christopher Steele was awarded the Sherman Knapp Scholarship for 1988-89. James Fox, an incoming student, has been offered and accepted this award for the academic year 1989-90. This particular scholarship is made possible through the generosity of Northeast Utilities.

Also at the April meeting, two undergraduate student awards were announced. Joseph Sorci was awarded the Irving Kaplan Award for the Outstanding Junior in Nuclear Engineering. Lisa Porter received the Roy Axford Award for the Outstanding Senior in Nuclear Engineering.

The Department of Energy recently announced that two of our students have been selected to receive a prestigious DOE Postdoctoral Fellowship. They are Robert Kirkwood, a graduate student in the applied plasma physics area, and Kevin Wenzel, a graduate student in the area of fusion reactor technology.

Several types of DOE fellowships supported a total of thirteen graduate students during the academic year. Daniel Lo, Justin Schwartz, and David Uy were funded by Magnetic Fusion Energy Technology Fellowships; Waste Management Fellowships were awarded to Steve Boerigter, William Holloway, Patrick Hogan, Vivian Leung, Tue Nguyen, and Kathy Yuracko; Nuclear Science and Engineering Fellowships supported Margarita Crocker, Vinh Dang, Jess Gehin, and Jerry Martin.

Other sources of graduate student financial support included the Institute of Nuclear Power Operations (INPO), Argonne National Laboratory, Stone & Webster Engineering Corporation, Pickard Garrick & Lowe, and Whitaker College. Students funded via these fellowships included Kevin Roberts, Youssef Shatilla, Ken Meyers, Guy Sasson, and Charles Carney.

In addition to the specific fellowships mentioned above, approximately two-thirds of the NED graduate student body received financial assistance as teaching and/or research assistants.

SUMMATION

As announced a short time ago, I have decided to step down as Department Head in order to devote more time and energy to my teaching and research activities. During the eight years since I assumed this position, I have had many and varied interactions with faculty, staff, support staff, and students. Without the continual cooperation and assistance that I have received, it would not have been possible to carry out the duties associated with this position. Since it is not possible to personally thank each one individually, I wish to use this opportunity to express my sincere thanks to every member of the department for their assistance and support during my term of office.

By now you may be aware that Professor Mujid Kazimi, a distinguished colleague and alumnus, has been selected as the next department head effective July 1. On behalf of myself and the entire department, I extend best wishes to Mujid as he becomes the fifth department head in the history of the nuclear engineering department.

NEIL E. TODREAS

Department of Ocean Engineering

OBJECTIVES OF THE DEPARTMENT

Last year, the Department developed a new statement of its objectives, with the following foci:

- o Naval Systems and Operations (with emphasis on undersea systems)
- o Deep-Sea Technology
- o Technology for Ocean Science

It was noted in the Department's report last year that the major immediate challenges for ocean engineering result from the need, in the civilian sector, for the offshore energy industry to produce oil and gas at deepwater sites (water depths greater than 1000 ft) and, in the military sector, for the Navy to develop new submarine and anti-submarine warfare (ASW) systems to meet newly evolving threats. Longer-range challenges relate to (i) the inevitable need to exploit the oceans further as a source of minerals, food, and energy and as a repository for ocean wastes, (ii) the developing crisis in the quality of the global environment, and (iii) the importance of understanding ocean properties and dynamics in support of all the foregoing thrusts. In focusing on the three areas listed above, the Department will provide education and produce new knowledge relevant to all of these short-and long-term challenges.

In February this year, the MIT Corporation's Visiting Committee for Ocean Engineering met to discuss the Department's programs and operations, and it endorsed the Department's vision of the future of ocean engineering. It especially commended the new emphasis on submarine and ASW systems on the military side, and it recommended that environmental issues be placed among the highest-priority non-military concerns. The Department responded positively on the latter point, subject to its obtaining external funding for relevant research.

UNDERGRADUATE EDUCATION

Undergraduate enrollment in the Department's programs continues to be extremely low. In order to expose more students to the challenges of ocean-related problems, the Department decided this year to try a new approach, offering an in-depth learning experience to students who are not necessarily committed to a major in ocean engineering. This will consist of a two-term subject combining an at-sea project with the more traditional form of teaching. Several lecture modules will provide an introduction to some of the essential areas of ocean engineering, including acoustics, instrumentation, and wave dynamics. During the same period, the students will plan and prepare for their experiment, which will be conducted at sea between terms. In the second term, they will analyze the results and study some of its non-technology implications.

This two-term subject will have prerequisites that students in several other engineering departments will have completed by the middle or end of their sophomore year. The Department's intention in structuring the subject this way is to provide an attractive means for a larger number of students to become acquainted with current issues in ocean technology and to develop an appreciation for the basic interdisciplinary nature of ocean engineering, without having to abandon their commitments to earning degrees in their chosen fields.

Professor J. D. Nyhart and Associate Professor Harilaos N. Psaraffis developed and taught one of the Institute's new "context subjects," which provide MIT students with an opportunity to combine their engineering and science studies with nontechnology aspects of their field. The subject taught by Professors Nyhart and Psaraffis was "Negotiation in Engineering Systems," which built, in particular, on Professor Nyhart's unique experience in developing innovative, nonconfrontational approaches to resolving disputes. As with most of the new context subjects, enrollment was discouragingly low, but the two faculty members and the students considered the new subject a success in terms of the lessons learned.

GRADUATE EDUCATION

Next year, all accredited engineering programs at MIT will be reviewed. The Department has made a major break with tradition by requesting accreditation of its program in naval architecture and marine engineering at the master's (SM) level, rather than the bachelor's level. In seeking accreditation at the SM level, the Department can structure the entire (nominally) five-year program culminating in this degree, rather than defining separately a four-year program and a follow-on one-year SM program. It is expected that a broader program of education can thus be provided, including increased consideration of the nontechnological implications of engineering practice.

SPECIAL STUDENT PROJECTS

Ocean Engineering students and faculty have been involved in four unusual extracurricular projects of some interest:

Human-Powered Submarine. With direct support and guidance from the staff of the MIT Sea Grant College Program, a group of students designed, built, and raced a human-powered submarine in a competition in Florida. The race itself was marred by bad weather, which precluded the main events from even being attempted; the rough, turbid water made it impossible to find the underwater course markers. So the outcome depended on performance in a straight-line 100-yard dash, which was won by the team from the US Naval Academy. The MIT submarine, however, won a prize as the best student design.

Professor Justin E. Kerwin also helped the team from the University of New Hampshire design the propeller for their submarine.

Human-Powered (Surface) Watercraft. A group of students in the Department of Aeronautics and Astronautics is designing a hydrofoil craft in which they will attempt to set a new speed record for a human-powered watercraft. Professor Kerwin and Associate Professor Dick K.-P. Yue have been advising the students on the hydrodynamic design of their vehicle.

Oar Design. A group of students, guided by Professors Kerwin, Yue, and A. Douglas Carmichael and supported by the MIT Sea Grant College Program, has been performing hydrodynamic and structural analyses and experiments in an attempt to achieve major improvements in the performance of the oars used in racing sculls. It appears that very little scientific attention has ever been given to this subject, and the students are learning how much improvement can be achieved through a careful, rational approach to oar design. They also have an opportunity to study important fundamental problems such as the separated (sometimes ventilated) flow behind blunt bodies. Two SB theses and possibly one SM thesis will result from this student project.

Concrete Canoe. Students in the Civil Engineering Department participated in a concrete-canoe race this year with a canoe designed by a student in the Ocean Engineering Department. Although this was the first time MIT has joined in this competition, the team won second place in a field of sixteen.

RESEARCH

Arctic Ocean Acoustics and Geophysics: Professor Arthur B. Baggeroer was the senior scientist for the Coordinated Eastern Arctic Experiment (CEAREX), which required the establishment of an ice camp at approximately 83N, 7E (north of Svalbard) from March to May this year. The objectives of the experiments encompassed almost all facets of ocean acoustics and geophysics, including ambient noise, long-range propagation, reverberation and back scattering, under-ice scattering, and seismic reflection and refraction. Important new components of this experiment included the Arctic Autonomous Measurement Platform (ARAMP) buoy for ambient noise studies and a 30-km acoustic array. The buoy contains a microprocessor that logs data to an optical disk. It is designed to permit the use of a complete set of environment-measurement (meteorological, CTD, current meters, etc.) sensors plus hydrophones and accelerometers. The data can be stored on the disk for recovery, and portions can be transmitted to satellites and/or air-craft via rf links. The 30-km array is the largest ever deployed in the Arctic. It is self-positioning and can locate its elements to within three meters in a 30-km aperture.

Scattering and Propagation of Sound Fields: The scattering of sound from rough interfaces between media and, generally, the properties and behavior of ambient noise affect practically all applications of ocean acoustics. Associate Professor Henrik Schmidt and his students have developed a formulation of non-Kirchhoff scattering and implemented it in his general propagation code, SAFARI. An important source of ambient noise in the Arctic is ice cracking; depending on the ice-cracking mechanism, this noise can be highly directional. Professor Schmidt has developed a numerical model for different cracking mechanisms and is now analyzing the sound fields produced by thermal cracks and comparing the results to experimental data. More generally, in evaluating different theories for noise-generation mechanisms, it is important to be able to determine the environmental propagation effects and subtract these from the measured field. A numerical model that Professor Schmidt developed in collaboration with personnel of the Naval Research Laboratory is now being used for simulating low-frequency wind-generated noise in shallow water. By removing the propagation effects from actual experimental data, they have demonstrated a high degree of consistency in the source levels observed in different environments.

Structural Acoustics: Professors Baggeroer, Ira Dyer, and Richard H. Lyon (Mechanical Engineering Department) are supervising research in a new Department of Defense program on structural acoustics. This program, which is being funded at a level of \$1 million per year for five years, is a key component of the new Submarine Technology Program of the Defense Advanced Research Projects Agency, although it is being administered by the Office of Naval Research. The objective is to understand the mechanisms by which sound is transmitted through a very complex structure and into the surrounding water. Of particular interest in the former is the dispersion of waves in structural systems complicated by attachments such as springs and masses; it appears that stop-bands may be created, possibly just by the judicious arrangement of the many machinery and other elements that are attached to any complex ship structure.

Computer-Aided Design and Manufacturing. There are currently four essential needs in the rational application of computers to the design and manufacturing of complex systems such as ocean platforms:

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- 1) a general method to model design features and intent during the creation and representation of complex objects in a computer environment, including the capability of extracting such features from geometric representations for driving automated analysis and manufacturing;
- 2) a general theory for incorporating tolerancing information for manufacturing into the computer model of the object during design;
- 3) a general method to model complex manufacturing processes, e.g., welding and forming, during design;
- 4) a general method to link robotic sensory fabrication with design data, particularly for complex tasks such as subsystem positioning and assembly into more complex structures.

Professor Chryssostomos Chryssostomidis and Assistant Professor Nicholas M. Patrikalakis (who formulated the above statement of issues) are systematically developing capabilities to answer these needs. In collaboration with faculty in the Departments of Material Science and Engineering and Mechanical Engineering, they have undertaken a project directed toward 3). Professor Patrikalakis and his students have solved one of the most important problems in 1), namely, how to represent shapes and their intersections through the use of rigorous, robust algorithms; the interrogation of implicit polynomials expressed in the B-spline basis allows the development of an adaptive, dynamic method. Professor Chryssostomidis has focused largely on the data base created during the design process, which must be capable of representing non-manifold systems, addressing issues of complexity, and providing means of capturing the designers' intent. The representation of non-manifold systems is necessary to permit design and abstraction to exist in the same data base. The general problem of complexity is being approached through the development of a hierarchical data base.

The first transfer of some of this new technology to a real-world problem is now taking place. Surface approximation with very high precision is a crucial problem in the design and manufacture of the most advanced marine propellers. The approach to surface definition developed by Professors Chryssostomidis and Patrikalakis is proving to be directly applicable to this problem. In addition, contacts have been established with industry to determine the critical issues from their point of view. Two such issues have been identified, the need for a good large-scale metrology system and for a system to permit flexible automation. Some aspects of the research already performed have contributed to finding solutions to these problems, and Professor Patrikalakis has been developing a new approach to form recognition ("localization") to make possible a new generation of flexible automation capabilities.

Submarine-Flow Mapping. Professor Justin E. Kerwin has, for about five years, been developing equipment and instrumentation to create complete maps of the flow around a submarine model at a large angle of attack. This is a critical issue in determining why submarines experience potentially disastrous pitch moments during hard turns. Now Professor Kerwin has extended this capability to the dynamic situation in which the model undergoes a "coning" motion, that is, it has not only a large angle of attack but a large rate of change of angle of attack. This is a unique measurement capability in the nation.

Tension in Towlines. Professor Jerome H. Milgram and his students have developed a theory for the nonlinear tension in towlines during operations in ocean waves. The computer code based on the theory has been used in producing a large data base for generating the statistics of extreme towing tensions. The data base in turn was used to generate a method of practical estimation of extreme tensions, which has been incorporated into the new US Navy Towing Manual. The theory is now being extended to include effects of the low-frequency motions caused by second-order wave forces.

Sail Forces. Professor Milgram designed a special sailboat that is, in effect, a sailing dynamometer, the sails being supported entirely on a structure that is separate from the hull except for the load cells that form the dynamometer. The boat was launched in 1988 after two years of design and construction. In addition to sail forces, measurements are being made of keel angle, pitch angle, boat speed, sailing direction, and wind-speed distribution (with height). All measurements are collected with an on-board computer. Both the approach to obtaining data and the vessel are unique.

Short Sea Waves. Microwave remote sensing has become a major means of studying a variety of ocean phenomena. Most of these measurements depend on backscatter from very short sea waves, and so it has become necessary to understand the mechanisms by which such waves are generated. Professor Milgram has shown that the energy transfer from nonlinear long-wave interactions to short waves is comparable to the rate at which wind fluctuations generate short waves. During the year, he also used for the first time equipment that he designed and built for measuring the short-wave spectrum in the wake of a ship.

Smart Underwater Vehicles: Associate Professor Michael S. Triantafyllou is working on a joint Sea Grant/ Draper Laboratory project to develop "intelligent" autonomous underwater vehicles. In particular, he is developing a vortex-tracking vehicle, based on artificial-intelligence (AI) techniques and knowledge of vortex dynamics; the vehicle will be able to detect variations in the vorticity field in the ocean and find locations of high vorticity. Professor Triantafyllou is also a key participant in the Argo/Jason Project of the Woods Hole Oceanographic Institution (WHOI); he has focused on the analysis of the behavior of the tether. In the summer, some aspects of the theoretical model were tested at full scale in the Mediterranean Sea, producing spectacular confirmation of the theory.

Extreme Loads and Structural Failure: Professor Tomasz Wierzbicki, Dr. W. Abramowicz, and an ocean engineering student have formed an internationally acclaimed research team in the area of crashworthiness engineering. Their general objective has been to develop simplified analysis tools for designing crashworthy components of structures. This year has been a milestone in this program, the highlight being the development of a specialized computer graphics tool for visualization of crash events, which made possible the development of a basic ingredient in the folding of thin-walled structures, the "superfolding element." This work has been supported largely by the world automobile industry, but now the Navy is recognizing its importance as well, and a new Navy-funded project has been started on the dynamic rupture and tearing of sheet-metal structures, which Professor Wierzbicki will carry out in collaboration with Professor Frank A. McClintock of the Mechanical Engineering Department.

NEW ENDOWED PROFESSORSHIPS

This year two gifts were received by MIT for the endowment of chairs to which faculty in the Department of Ocean Engineering are being appointed:

Kawasaki Heavy Industries of Japan agreed to fund the Kawasaki Professorship to support education and research in the engineering of complex systems. Professor Koichi Masubuchi has been named as the first Kawasaki Professor for a five-year term starting July 1. The appointment of chairholders in the future is not restricted to faculty in the Ocean Engineering Department, but the term "complex systems," as used by Kawasaki Heavy Industries in its gift, is generally descriptive of activities in the Department of Ocean Engineering.

Dr. William I. Koch, through the Falcon Foundation, will endow the Professorship of Marine Technology. Dr. Koch specifically named the Ocean Engineering Department as the beneficiary of his gift. An appointment will soon be made to this chair.

FACULTY AND RESEARCH STAFF

Professor Arthur B. Baggeroer has been elected a Fellow by The Institute of Electrical and Electronics Engineers for his contributions to advanced array processing and underwater acoustics. This honor is reserved to a very limited number of individuals each year who have shown evidence of extraordinary qualification and achievement in the field of electrical, electronics, or computer engineering.

Professor Baggeroer's term as MIT Director of the Joint Program of the MIT/Woods Hole Oceanographic Institution ended in October.

Professor A. Douglas Carmichael continues as faculty head of the MITES Program, an activity of the School of Engineering to provide disadvantaged high school students with an enhanced background in mathematics and physics.

CDR Richard C. Celotto, USN, has been appointed to a faculty position for a three-year term as Associate Professor of Naval Construction and Engineering. He has distinguished himself in the technical management of the design and acquisition of a new class of Navy minesweepers. He will join the faculty this summer.

Professor Ira Dyer has been appointed to serve on an advisory panel of the Office of Technology Assessment (OTA) of the US Congress, which will make recommendations to OTA and the Congress on the mineral resource potential of Antarctica and evaluate the Convention on the Regulation of Antarctic Mineral Resource Activities.

Professor Ernst G. Frankel was appointed as the Principal US Representative to Permanent Technical Committee II of the Permanent International Association of Navigation Congresses (PIANC).

Associate Professor Judith T. Kildow has been appointed to the Marine Board of the National Academy of Sciences (NAS) and is serving on its Committee to Study the Health of the Technical Base of the Marine Sector. She was also appointed to the Committee on Coastal Erosion Management of the NAS Water Science and Technology Board.

Dr. F. Thomas Korsmeyer was appointed to the staff as Research Engineer to work with the Department's hydrodynamics faculty. He is working on the development of a new generation of matrix-inversion methods, which could lead to an order of magnitude improvement in the speed of solving many problems of ocean engineering that require the solution of very large sets of equations (typically containing many thousands of equations and unknowns).

Associate Professor Henry S. Marcus taught a short course, "Managing the Acquisition and Application of Technology in the Navy," for the staff of the Assistant Secretary of the Navy for Shipbuilding and Logistics.

Professor Koichi Masubuchi has been appointed the first Kawasaki Professor of Engineering at MIT. During the year, he became a life member of the American Welding Society, he was appointed Guest Member of the Japan Welding Society (an honor reserved for foreigners, Professor Masubuchi being only the third American so recognized), and he received a special citation at the Second International Conference on Welding Research for his "outstanding contributions to the field of welding science and technology."

Professor Jerome H. Milgram has been on sabbatical leave during the academic year. He devoted this period to research on ocean wave phenomena and the measurement of waves by synthetic-aperture radar.

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Professor J. Nicholas Newman received the Davidson Medal of the Society of Naval Architects and Marine Engineers for his distinguished accomplishments in research. He also presented the prestigious annual Weinblum Lecture to the Schiffbautechnische Gesellschaft in Berlin and at the National Academy of Sciences in Washington. Professor Newman has been on sabbatical during the academic year.

Assistant Professor Nicholas M. Patrikalakis's appointment as Doherty Professor of Ocean Utilization continued this year.

Associate Professor Harilaos N. Psarftis resigned at the end of the year to accept a position as Professor at the National Technical University Athens.

Associate Professor Paul E. Sullivan, an active-duty officer in the US Navy, resigned in June to accept a new assignment for the Navy. He was awarded the Meritorious Service Medal by the President of the United States for the performance of his duties while he was assigned to MIT, and he was promoted to the rank of Commander this spring.

Professor Barrick F. Tibbitts, CAPT, USN, received a citation from the Navy for his outstanding performance in handling a special assignment this winter at the Mare Island Naval Shipyard.

Dr. George S. Triantafyllou was promoted to Principal Research Engineer. He has become internationally known for his innovative research on the instability of flows past blunt bodies, which usually leads to the creation of large vortices. Dr. Triantafyllou works in collaboration with the staff and faculty of the Ocean Engineering Design Laboratory.

Professor Tomasz Wierzbicki has been on sabbatical leave during the year, spending most of it in research collaboration with engineers at BMW Motor Works in Munich, Federal Republic of Germany. Professor Wierzbicki received the Alexander von Humboldt Foundation Senior US Scientist Award this year.

Dr. Franz-Erich Wolter was appointed to the staff as Research Engineer. He is working with the staff of the Ocean Engineering Design Laboratory on problems involving the use of differential geometry in the representation of complex shapes in a computer.

Associate Professor Dick K.-P. Yue was granted tenure this year. He is widely respected for his innovative and thorough numerical solution of some of the most difficult problems involving the behavior of flows with a free surface.

ROBERT BRUCE WALLACE LECTURE

In October 1988, Dean Gerald L. Wilson presented the annual Robert Bruce Wallace Lecture, speaking on the future of engineering education in the United States. His talk established the focus of much of the subsequent discussion in the School of Engineering on the evolving fundamental mission of the School.

T. FRANCIS OGILVIE

Artificial Intelligence Laboratory

The primary goal of the Artificial Intelligence Laboratory is to understand how computers can be made to exhibit intelligence. Two corollary goals are to make computers more useful and to understand certain aspects of human intelligence. Current research in the Laboratory includes work on robotics, vision, natural language, learning, reasoning and problem solving, deep expert systems, engineering design, computer-aided programming, supercomputing, and basic theory.

Professor Patrick H. Winston works on the problem of learning from precedents. Professor Marvin Minsky develops general theories of intelligence and knowledge representation. Professor Robert C. Berwick studies fundamental issues in natural language, including syntactic and semantic acquisition. Professor David A. McAllester works on knowledge representation and automated reasoning. Professor W. Eric L. Grimson, Professor Ellen C. Hildreth, Professor Berthold K. P. Horn, Professor Tomaso A. Poggio, and Professor Shimon Ullman do research in computer vision. Professor Christopher G. Atkeson, Professor Rodney A. Brooks, Professor John M. Hollerbach, Professor Tomás Lozano-Pérez, Professor Marc H. Raibert, Professor Warren P. Seering, and Dr. J. Kenneth Salisbury work on various aspects of Robotics. Professor Randall Davis and Dr. Howard E. Shrobe work on deep expert systems that use both functional and physical models. Professor Karl T. Ulrich creates decision tools for product design and manufacturing. Dr. Charles Rich and Dr. Richard C. Waters explore the creation of intelligent programming environments. Professor Carl E. Hewitt studies distributed problem-solving and parallel computation. Professor William J. Dally is designing the J-Machine for efficient implementation of massively parallel message passing systems. Professor Gerald J. Sussman and Professor Harold Abelson lead a major new research program aimed, in part, at creating sophisticated problem-solving partners for scientists and engineers studying complex dynamic systems.

The Laboratory's 195 members include 22 faculty members, 10 academic staff, 38 research and support staff, and 125 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 Lockheed Missiles and Space Company, Machines, Martin Marietta, MCC Corporation, NASA, NATO, NYNEX, Olivetti, Sandia National Laboratory, Siemens, Sloan Foundation, and Sperry.

ROBOTICS

Mobile Robots

Professor Brooks and his staff and students have been building mobile robots and testing their theories of how to organize intelligence. They have made progress on three fronts; organizing many behaviors into a coherent whole, developing perceptual systems that work in rapidly changing environments without a priori calibration, and producing extremely tiny robots. During the past year, a totally autonomous robot was demonstrated working in an unmapped environment, visually locating an object of interest, grasping it and returning it to a particular location. Additionally, a six-legged robot capable of following people over rough terrain was demonstrated, with its coherent behavior emerging from 57 reflex reactions. Progress was made in building maps of unknown

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environments. A 1.25 cubic-inch robot was built and techniques and technologies for building a two millimeter diameter robot were invented and investigated.

Planning For Collision-Free, Compliant, and Grasping Motions

Professor Lozano-Pérez and his associates have continued development and testing of the Handey task-level robot system. The Handey system plans all the motions required for pick-and-place tasks involving planar-faced parts. Handey first locates one of the parts on the robot's work table, then plans where to grasp the part so as to avoid all nearby obstacles. Next Handey plans a collision-free path for the complete robot to reach the part, selects a sequence of regrasping motions (if necessary) to achieve a grasp compatible with the final destination, and finally, plans a path to place the part at the specified destination. Handey has recently been extended in several ways. Handey can now deal with jointed parts such as doors and cranks. Handey can now coordinate the motions of multiple robots. This new capability was achieved by viewing the robot coordination task as a variant of deadlock prevention problem in distributed databases. Handey can now grasp complex polyhedral objects using Dr. Salisbury's three-fingered hand. To achieve this, the system plans the motion of the finger tips so as to guarantee a grasp that is both stable and reachable.

Legged Locomotion

Professor Raibert and members of the Leg Laboratory have been studying legged locomotion in robots and animals. In earlier years the group demonstrated dynamic machines that balanced as they ran. This work included one-, two-, and four-legged machines that ran in place, traveled at specified rates, maintained balance when disturbed, ran fast, and did simple gymnastic maneuvers. New algorithms were developed for studying passive dynamic running and a three-dimensional biped is now operational. One running machine ran on stilts to accomplish a new top speed of 13.1 mph. Experiments with a quadruped demonstrated the ability to switch between trotting, pacing, and bounding gaits. Students have built a new one-legged machine with two feet that simulates running in zero-gravity: it was designed to travel in a hallway by bouncing off opposite walls.

Robot and Human Arms and Hands

Professor Hollerbach's research involves two major thrusts: the kinematics, dynamics, and control of human arms and robot manipulators; and the grasping, tactile sensing, and haptics of human hands and multi-fingered robot hands. With Professor Ian Hunter of McGill University, he has been measuring the joint mechanical properties of the unrestrained human arm during posture and movement, using a novel perturbation system involving air jets. He has developed a new technique for robot arm kinematic calibration, involving the use of closed-loop mobility rather than endpoint sensing. With Professor Jeffrey Lang of the Laboratory for Electromagnetic and Electronic Systems and Professor Hunter, he has been designing and testing new motors for a direct-drive arm. With Mr. Nat Durlach of the Research Laboratory of Electronics, he has been measuring the perceptual capabilities of the human hand.

The Salisbury articulated hand has been mounted on a PUMA arm and has served as a test bed for a wide range of grasping and path planning experiments. Dr. Salisbury's group is currently using this hand/arm system to develop reflexive grasping behaviors aimed at plan-free object acquisition in both terrestrial and zero-gravity environments. The integration of three six-axis force sensing fingertips into the system has provided the sensory information necessary for implementing a new grasp-force redistribution reflex for securely handling delicate objects. Professor Lozano-Pérez's group has been using this system to demonstrate and develop their geometry-driven grasp planning system. A system which recognizes objects from kinesthetic information is also being developed for the hand.

A new high performance cable driven arm (WAM), developed by Dr. Salisbury's group, has been the focus of a number of novel manipulation and control investigations. The arm takes advantage of its inherent force controllability in performing a new class of operations known as *whole-arm manipulation*. Because the arm is designed to perform useful operations with all its surfaces, not just its end-point, it is able to push, grasp, and operate upon objects in ways impossible for traditional robots. Professor Slotine of MIT's Non-Linear Systems Laboratory has developed and implemented a series of adaptive non-linear control systems for the WAM arm which permit significantly improved performance, particularly in the constantly changing dynamic environment in which the arm operates. A second version of this arm has been developed in conjunction with Dr. Yoerger at the Woods Hole Oceanographic Institute and was used successfully during their recent deep ocean explorations in the Mediterranean Sea.

Advances have been made in understanding the dynamic characteristics of robot arms. This work has led to strategies for improving robot performance in several areas. Structural vibration of robots has traditionally resulted in unacceptable endpoint motions, particularly for light flexible arms. Within Professor Seering's group, methods have been developed for moving flexible robots rapidly from point to point without exciting undesirable vibrations. A test system has been designed for evaluating these methods. The effects of changes in system configuration on system performance are currently being studied.

Professor Seering's students also have been studying the problem of programming computers to perform certain components of the mechanical design process. A program has been written to transform a schematic description of a design to a detailed design by optimally choosing system components. This work has led to new insights about representation of design specifications.

Motor Learning

Professor Atkeson and his group have been exploring paradigms for motor learning, improving performance with experience in humans and robots. Previous work focused on parameter identification, model and coordinate system calibration, and model-based control. An important emphasis has been model-based learning, where a model of the controlled system is used as the learning operator to map performance errors into command corrections. Models of a task can be used in addition to models of the system components to accelerate learning. Another area of research has been memory-based learning algorithms, where an associative content addressable memory is used to learn an internal model and improve robot performance on a particular task.

VISION

The Vision Machine

The main project of Professor Poggio's group has been the Vision Machine—a computer system that attempts to integrate several visual cues to achieve high performance in unstructured environments for the tasks of visual recognition and navigation. The Vision Machine is also a test-bed for their progress in the theory of early vision algorithms, their parallel implementation, and their integration, up to recognition of 3D objects. The Vision Machine consists of a movable two-camera Eye-Head system—the input device—and a Connection Machine—the main computational engine. They have developed and implemented several parallel early vision algorithms computing edge detection, stereo, motion, texture, and color in close to real time. The integration stage attempts to derive a map of the surface discontinuities in the scene, with a partial labeling of the intensity edges in terms of their physical origin. They have interfaced the output of their integration stage with a parallel recognition algorithm. They are also beginning to study analog and hybrid VLSI implementations of the Vision Machine's

main components. Thus the project has several complementary goals: it attempts to develop a theory of visual integration and to test it in an unstructured environment; it aims to refine and implement robust early vision algorithms in a massively parallel architecture; and it tries to build a full vision system. They are now focusing their work on recognition and on Machine Learning. In particular, they have begun to explore simple learning and estimation techniques for vision tasks. They have succeeded in synthesizing a color algorithm from examples and in developing a technique to perform unsupervised learning of other simple vision algorithms such as simple versions of the computation of texture and stereo. In particular, they have developed a new theory of networks for learning that appears well-founded and general enough to include several existing approaches as special cases. The approach is based on the recognition that learning input-output mappings from sets of examples, of the type that many neural networks have been tested on, can be regarded as synthesizing an approximation of a multi-dimensional function, that is, solving the problem of hypersurface reconstruction. From this point of view, this form of learning is closely related to classical approximation techniques, such as generalized splines and regularization theory. They have developed a general theoretical framework that shows the equivalence between regularization and a class of three-layer networks that they call Generalized Radial Basis Functions (GRBF). GRBF appear to be a general and powerful technique for many learning problems and in particular for the problem of learning in machine vision. Towards the goal of achieving much higher flexibility in the Vision Machine they propose to explore (a) the synthesis of vision algorithms from a set of instances and (b) the refinement and tuning of preprogrammed algorithms, such as edge detection, texture discrimination, motion, color and calibration for stereo. Much of their effort will be focused on new schemes for visual recognition of 3D objects, whose key component is the automatic learning of a large database of models. They aim to develop a prototype of a flexible vision system that can, in a limited way, learn from experience.

Stereo Vision

Professor Grimson and his students continue to work on the development of new stereo vision systems, and on their use in intelligent tasks. Recent highlights include a new stereo matching algorithm, the integration of stereo into a navigation system for a mobile robot, and some preliminary work on object recognition from stereo data.

Recognition

Work on object recognition, directed by Professors Grimson and Lozano-Pérez, has centered on the development of systems for recognizing objects in cluttered, noisy, unstructured environments. Such systems have been demonstrated in a variety of environments, using visual, laser, sonar, and tactile sensors. They have also been incorporated as part of a hand-eye system, and as part of a navigation system for autonomous vehicles. Recent efforts have focused on establishing formal results on the complexity of object recognition, on parallel algorithms for recognition, on the role of sensing strategies in recognition, and on methods for selecting salient data features on which to focus attention.

Other work directed by Professor Ullman and his students is exploring the problem of three-dimensional object recognition. This research has been divided into two main topics. The first problem is that of image partitioning and selection, the goal of this processing stage being to select from the image a portion that is likely to contain an object of interest. The selection processes give the recognition system a capacity that is similar to the use of selective attention in human vision: it allows the system to concentrate its computational resources on the selected structure and apply to it additional processing stages that will lead eventually to recognition. Professor Ullman and Mr. A. Sashua are working on this selection and partitioning process.

The second topic is the representation of three-dimensional objects in memory, and the matching of these memory models with two-dimensional objects in the image. Towards this end, Professor Ullman has developed an approach

called the alignment method. In this method, the transformations separating the viewed object and a given stored model are discovered and compensated for prior to the matching operation. The scheme, initially implemented for flat machine parts, has recently been extended to handle complex three-dimensional objects with smooth surfaces such as different car models.

Photogrammetry

Professor Horn and his students continue to work on problems in motion vision. Currently, the connection between motion vision and photogrammetry is being explored. One of four central problems in photogrammetry is the recovery of the relative position and orientation of two cameras used to image the same scene. A new iterative algorithm, that finds all solutions without requiring a good initial guess, has recently demonstrated that this old problem can have up to twenty solutions. Solutions come in groups of four, except at boundaries in parameter space, which correspond to so-called critical surfaces, where they come in groups of two. The parameters of the coordinate transformation between cameras cannot be determined accurately when the measured points lie on or near a critical surface, so detailed analysis of these surfaces is indicated. They have shown that only certain hyperboloids of one sheet and their degenerate forms can qualify. The close connection between motion vision problems and those of binocular stereo have been illustrated by the fact that critical surfaces arising in motion vision belong to the same class of quadric surfaces (although their interpretation is somewhat different).

Photoclinometry

Astrogeologists interested in recovering surface topography from images obtained using optical means or synthetic aperture radar (SAR) have a great interest in *photoclinometry*, which is their term for what is called *shape from shading* in machine vision. Professor Horn introduced the astrogeological community to area-based methods (as opposed to the inferior profile-based methods now used) at the first ever workshop on photoclinometry held at Arizona State University last February. In preparation for this, a new algorithm was developed that can deal with complex, wrinkled surfaces without the distortion that normally arises from the use of regularization. This algorithm has since then been further refined and applied to a variety of synthetic images, which demonstrated for the first time convergence to exact solutions, given adequate boundary conditions. In a related development, it has recently been shown that there exist *impossible shaded images*. There had been conjectures that there might be images that could not correspond to shading on any surface (under assumed lighting conditions), but it took the impetus of a contest prize to elicit a proof!

Visual Motion

Professor Hildreth's research addresses the analysis of visual motion. Her recent work focuses on the recovery of the three-dimensional motion and structure of objects, and followed three directions. The first is the computation of qualitative or partial information regarding 3-D structure and motion for tasks such as navigation. She developed a model that uses simple estimates of time-to-collision, based on the changing image size of moving objects, to reconstruct their 3-D trajectories through space, and is conducting perceptual experiments to test whether such a strategy is used by the human visual system. Second, she has been exploring the integration of 3-D structure-from-motion recovery with the overall process of surface reconstruction. This latter project has led Professor Hildreth to study the interaction between motion analysis and binocular stereopsis. She is pursuing a model that computes the 3-D positions and velocities of features over an extended time, through incremental improvement, by combining constraints both from the projected 2-D motions of the points in the image and the temporal changes in their stereo disparity.

NATURAL LANGUAGE

Professor Berwick and his colleagues have been building the next generation of natural language parsers and translators, based on modular linguistic theories. During the past year, a completely modular parser for English was implemented that allows one to investigate different constraint-ordering possibilities so as to optimize language processing. This is the first complete parsing implementation of the current linguistic theory that has been developed at MIT by Chomsky, Hale, Higgenbotham, and others. The system also includes a learning component to automatically "compile" its constraints into those required for optimally parsing a given sentence. His group also improved on a universal representation for word meaning that considerably advances existing language translation systems, successfully applying this method to problematic translation examples in Spanish and German. Finally, a new collaborative effort into the design of modular language processors was continued jointly with the Cognitive Science Center. This has included the analysis of a million-word English language database and the design of tools for "smart" dictionary analysis for several very different languages.

LEARNING AND COMMONSENSE REASONING

Professor Winston's theory of reasoning by analogy consists of an English understanding module, developed and implemented by Dr. Boris Katz, an analogizing module that reaches conclusions about a given situation by using a remembered precedent, and a rule builder that constructs if/then rules. The system has been extended in the past year so that rules can now be repaired by exploiting knowledge gleaned from situations in which learned rules are triggered when they should not have been. The repair involves a generalization of the near-miss idea to isolate exactly why the errant rule triggered when it should not have.

Continuing work includes a study directed at programs that design experiments to distinguish competing theories. These discovery programs, called *inquisitive systems*, learn by synthesizing new representations based on empirical analysis and experimentation in a real or simulated world. The programs that design experiments extend previous work, exploring theoretical questions concerning the computational complexity of experiment design for various classes of theories.

New work includes an effort to use analogical reasoning in situations traditionally approached by decision theory. The key problem is to find a suitable, framelike vocabulary for describing decision processes. The selection of computer hardware, for example, is an exercise repeated many times, often within the same organization. By capturing such a decision process in a form that facilitates symbolic reasoning, subsequent decisions need not go over the same ground. Additionally, decision can be seen from a variety of perspectives, providing a sort of symbolic what-if capability, leading to a better understanding of how biases influence conclusions.

MODEL BASED REASONING SYSTEMS

Professor Davis, Dr. Shrobe, and their associates are building knowledge-based systems that use models of structure, function, and causality to perform a wide range of problem solving and reasoning tasks. The systems they have built can reason about how a device works and how it fails in a manner similar to an experienced engineer. This is an important advance in the art of knowledge-based systems construction, because it provides the system with a more fundamental understanding of the device than is possible using the traditional approach.

Work in the past twelve months has been characterized by the completion of a number of systems that reason in this fashion, including: a troubleshooting system that can apply these techniques to designs that include memory and complex time-dependent behavior; a system that generates diagnostics from a circuit description, capable of generating tests for devices considerably more complicated than those handled by existing test generators;

a system that functions as an assistant in design for testability; a system that designs devices by reasoning from fundamental principles of qualitative physics and qualitative mathematics; a system to demonstrate how a program can learn from experience, using two different forms of generalization along with a set of guidelines that indicates when to remember and generalize, and when to simply re-derive the result; and a system capable of designing representations for an interesting class of analytical reasoning problems.

Work has also begun on two new systems. One has been designed to aid in consensus knowledge acquisition, the task of assisting two or more experts in coming to consensus on the knowledge base necessary for a specific task. The second was designed to explore the fundamental problem of model selection: how does an engineer decide which model (that is, which approximation) to use when solving a problem.

ENGINEERING PROBLEM SOLVING AND DESIGN

Professor Ulrich and his students have been working on computational tools for product design and manufacturing. One project aims at communicating accurate manufacturing cost information to a product engineer at the detailed design stage of product development. Another project develops a human-computer interface for geometric modeling in product design. This interface is a kind of intelligent modeling clay in which an engineer's hand actions are interpreted as operations on a graphical description of a part. Professor Ulrich also been working on the problem of synthesizing an engineering structure in response to a specification of its connections to other parts of a product. The work is currently focused on sheet metal parts such as brackets in a photocopier. Finally, Professor Ulrich uses the 16,000 processor Connection Machine to develop novel schemes for simulating the mechanical behavior of materials.

PROGRAMMER'S APPRENTICE

Dr. Rich, Dr. Waters, and other members of the Programmer's Apprentice group have been using programming as a domain for studying and attempting to duplicate human problem solving skills. In the near term, they seek to produce a system, called the Programmer's Apprentice, which provides intelligent assistance in various phases of the programming process. They have made significant progress in three areas. Using the *cake* knowledge representation and reasoning system developed in the group, a system has been constructed that assists in the localization of software errors. Again using *cake*, work is nearing completion on a Requirements Apprentice, which can assist in the process of developing complete and consistent requirements. Work is just starting on a Design Apprentice, which will extend the capabilities of the Programmer's Apprentice into the area of low-level design.

MIXED SYMBOLIC AND NUMERICAL COMPUTATION

The research of the MIT Project for Mathematics and Computation (Project MaC), under the direction of Professors Abelson and Sussman, is aimed at developing new computer representations and reasoning mechanisms that will enable intelligent systems to autonomously design, monitor, and understand complicated physical systems through appropriate mixtures of numerical and symbolic computing. Over the past year members of the group have shown how to use symbolic algebra to compile high-level descriptions, such as circuit diagrams, directly into numerical modeling and simulation programs whose elements can be automatically generated from a library of mix-and-match numerical subroutines expressed at appropriate levels of abstraction. Work by Abelson (the Bifurcation Interpreter), Yip (KAM), and Sacks (PLR) have demonstrated how to encode knowledge of modern dynamical systems theory into intelligent programs that automatically control and monitor numerical experiments and interpret the results in qualitative terms. They are also developing a *Supercomputer Toolkit* that supports the routine, or even automatic, synthesis of high-performance but low-cost special-purpose computers.

ROBUST ULTRACONCURRENT SYSTEMS

Message-Passing Semantics

The Message-Passing Semantics group, under the guidance of Professor Hewitt, has been developing the foundations for ultraconcurrent systems that perform robustly in changing environments. An ultraconcurrent system is one that performs its computations as rapidly as possible compatible with the laws of physics. The primitives of ultraconcurrent systems are called ACTORs which are organized into systems called ORGs (Organizations of Restricted Generality). The Message-Passing Semantics Group has been developing the science of technology for robust ultraconcurrent computer systems, where robustness means the ability to keep commitments in the face of conflict and indeterminacy. Robust computer systems are needed to meet the challenge of Open Systems, which is to gain from the advantages of openness while meeting the requirements that are imposed by openness. Open systems undergo continual change: some change coming from within, through communication among internal parties, some from without through interaction with the environment. The Actor model provides a scientific and technological basis for open systems because it supports dynamic reconfigurability, compositionality, and extensibility. The ORG model provides a scientific and technological basis for organizational systems because it supports teamwork, management, liaison, operations, and organizational representation. The group's research focuses on theoretical, architectural, and linguistic aspects of organizational systems composed of humans and telecomputer systems.

Symbolic Parallel Architectures

The Symbolic Parallel Architecture group, under the direction of Professor Knight, has been developing a uniform, large scale, parallel symbolic supercomputer called *Transit*. Unlike most parallel machines, this architecture has been explicitly designed to support a wide range of parallel programming models with excellent performance. The key realization is the critical importance of low latency in the processor-to-processor communications path. This low latency communications is used as a substrate for coherent caches and processor to processor message passing. The implementation of *Transit* is being done in three phases: construction of the routing network, coherent cache implementation, and finally processor design. The routing network is currently under detailed design and simulation. Its construction involves novel three-dimensional packaging and cooling technology, novel VLSI techniques for chip to chip communications, and a very simple, high speed routing component. The initial prototype is expected to yield a remote memory access latency of about 300ns and a per-port peak bandwidth of 800 megabaud. The aggregate switch bandwidth approaches a terabaud.

Initial design of a massively parallel hybrid analog/digital machine for quickly solving coupled constraint problems has also begun. The architecture capitalizes on the ability of resistive meshes to express and solve constraint and optimization problems. Dynamic problems can be solved using a new approach of converting dynamic systems into four-dimensional static problems. The temporal evolution of solutions is then available in a spatially accessible array.

Concurrent VLSI Architecture

The Concurrent VLSI Architecture Group under the direction of Professor Dally has been developing techniques for applying VLSI technology to solve information processing problems. The group has been working on the design of the J-Machine, a fine-grain concurrent computer that offers performance of 10^3 times a conventional mainframe and tests a number of new concepts in interconnection networks, addressing mechanisms, processor

architecture, computer arithmetic, and concurrent software systems. The group has completed the register-transfer level simulation of the machine and begun detailed design in collaboration with Intel corporation. An operating system kernel and a Concurrent Smalltalk compiler have been written for the machine. A routing chip and an arithmetic chip designed to test portions of the J-machine design were successfully demonstrated in the laboratory.

BASIC THEORY

Professor McAllester has been building and testing automated reasoning systems. These reasoning systems incorporate a variety of new algorithmic techniques that allow effective automated reasoning about topics that are beyond the scope of any previous reasoning system. For example, the new reasoning systems have been able to verify proofs, starting with only the axioms of Zermelo-Fraenkel set theory, of the Stone representation theorem in lattice theory. This theorem involves an ultrafilter construction and is similar in complexity to the Tychonoff theorem that a product of compact topological spaces is compact. The novel algorithmic techniques include the integration of congruence closure into general theorem proving, monotone closure for reasoning about semantic types, focused forward chaining, and the incorporation of universal generalization into constraint propagation. A variety of new automated reasoning algorithms are currently under development. The power of an automated reasoning system can be measured quantitatively by measuring the length of the text required to guide the automated reasoning system to a verification (or proof) of a statement. The quantitative results on the Stone representation theorem suggest that machine verification of arbitrary mathematical theorems will be practical in the not too distant future. 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. There is a continuum between "syntactic" type checking, as done by current compilers, and the theoretically possible, but not yet demonstrated, "semantic" type checking. Semantic type checking is technically equivalent to program verification and his automated reasoning systems appear particularly well suited for this application. Professor McAllester also does research in many of the traditional areas of artificial intelligence, including computer game playing, planning, automatic programming, and common sense reasoning.

Professor Minsky has continued to develop the theory of human thinking and learning called the "Society of Mind". This theory explores how phenomena of mind emerge from the interaction of many disparate agencies, each mindless by itself. For example, one aspect of the theory explains the combination of knowledge representations in different realms of thought as the basis for analogy; another aspect is a "re-duplication" account of natural language, in which grammatical forms are seen as emerging directly from expressive requirements rather than from conventions that communications are forced to fit.

Professor Minsky has continued his interest in the limits and potentials of "connectionist learning systems" and their role in distributed cognitive accounts like the Society of Mind. He is actively considering how such systems may be combined and interconnected in a way that avoids the serious scaling problems of unstructured connectionist systems.

PATRICK H. WINSTON

Biotechnology Process Engineering Center

The Biotechnology Process Engineering Center (BPEC) is an interdepartmental Center at the Massachusetts Institute of Technology. This Center is funded by the National Science Foundation (NSF) under the Engineering Research Center Initiative and was established in May, 1985. This Center was approved in 1987 for an additional five years of support beginning February, 1988 through January, 1993. As an interdepartmental Center, the BPEC reports to the Dean of Engineering, Professor Gerald L. Wilson. The Director of the Center is Daniel I.C. Wang, Professor of Chemical Engineering. Three Associate Directors assist in the overall operations of the Center. These include Charles L. Cooney, Professor of Chemical Engineering and Associate Director for Industrial Involvement, Gregory N. Stephanopoulos, Professor of Chemical Engineering and Associate Director for Research, and Anthony J. Sinskey, Professor of Biology and Associate Director for Education and Cross-Disciplinary Affairs.

The goal of this Center is to create a new breed of professionals to enhance this Nation's international competitiveness in biotechnology manufacturing. To achieve this goal, this Center focuses its efforts through education, research and industrial involvement. Cross-Disciplinary educational and research collaborations are especially important components within the Center's activities. Thus, in the past year, this Center has placed priority emphasis on fostering and increasing its intra-disciplinary and inter-disciplinary collaborations.

In 1988, a total of 12 faculty members participated in the Center's activities. Within MIT, two departments from the School of Engineering have faculty participants and these are the Department of Chemical Engineering and the Department of Electrical Engineering and Computer Science. From the School of Science at MIT, faculty participants are from the Biology Department and the Whitehead Institute. This Center also has two outside universities which participate in the overall activities. These are from the Department of Chemistry at Harvard University and the Department of Chemical Engineering and Biochemical Engineering at Rutgers University.

A summary of the personnel associated with this Center during 1988-1989 is tabulated below.

• MIT Undergraduates (UROP)	- 78 (8 Departments)
• Non-MIT Undergraduates (REU)	- 28 (12 Universities)
• Graduate Students	- 53 (4 Departments)
• Technical Assistants	- 7
• Post-Doctoral Associates	- 21
• Visiting Scientists & Engineers	- 19
• Visiting Faculty	- 5
• Other Administrative Personnel	- 9

TOTAL 220

The major financial support is provided by the National Science Foundation. Additional support for educational activities for the MIT students is partially provided by the National Institutes of Health (NIGMS). Additional financial support in the forms of industrial contracts and equipment donations were provided by 34 companies. Lastly, unrestricted funds to the Center and its faculty in 1988-1989 were provided by 79 companies.

EDUCATIONAL ACTIVITIES

The Center's faculty members continue to teach an interdisciplinary undergraduate course, 7.52J/10.56J, "Biotechnology of Mammalian Cells". The funds to the faculty and teaching assistants for implementing this course were provided by the Center. This course had a total enrollment of 15 students from 4 departments. The Undergraduate Research Opportunities Program (UROP) continues to be an active program within the Center. In 1988-1989, a total of 78 MIT undergraduates from eight departments participated in the Center's research. An undergraduate outreach program funded separately by the National Science Foundation under the Research Experience for Undergraduates (REU) supported 28 non-MIT students in 1988-1989. These non-MIT REUs were from 12 different universities and colleges throughout the United States. A new Seminar Program entitled, "UROP and REU Seminar" was initiated where the undergraduates present on a weekly basis their research experiences to the Center's personnel.

At the graduate level, efforts were continued to bringing interdisciplinary concepts into the course teachings. During January, 1989, two of the Center's faculty members also participated in the teaching of biotechnology processes and manufacturing in the new course, 15.963, "Managing Technology-Based Products and Processes", established by the Sloan School of Management.

Industrial educational activities were achieved through the Special Summer Course Program at MIT. In 1988, four special summer courses under the auspices of the BPEC were presented. The four summer courses were, "Fermentation Technology", "Biotechnology: Principles and Processes", "Downstream Processing", and "Modeling, Simulation and Optimization of Chemical Processes". During 1988, a four-day course on "Downstream Processing" taught by five BPEC faculty members was presented at Merck, Sharp and Dohme's West Point facility.

CURRENT RESEARCH

The vision and goal of this ERC are to develop advance concepts for the manufacturing of complex proteins and to train a new breed of professionals with the cross-disciplinary skills needed to support the biotechnological industry. Many therapeutic proteins cannot be made in prokaryotic organisms and thus new concepts are needed to synthesize and recover these materials from animal cell cultures. The research thrusts of the BPEC are designed to solve near and long term problems, and as such, have impacted on US biotechnological manufacturing capabilities and international competitiveness. Training people, performing research and working with industry are central BPEC goals and are the mechanism through which we will deliver the benefits of our work.

Three research thrust areas are being pursued in this Center. The first area is focused on the "Genetics, Molecular Biology and Biochemical Principles in Protein Production". The overall goals are to find generic means for the genetic construction and identification of animal cells to increase recombinant protein expression and secretion leading to increased levels of recombinant proteins in eukaryotic cells. A novel gene amplification strategy has been developed to increase gene copy number using an SV40 vector in combination with temperature sensitive mutants. This finding provides a new method for both rapid selection and high level expression of recombinant proteins. Two important goals are to better understand post-translational protein modification and protein secretion. Achievement of this goal is important to the development of advanced manufacturing processes. A bottleneck in the transport of recombinant proteins in the endoplasmic reticulum proteins has been found; by unraveling this rate controlling step, we should increase the rate of protein secretion. A cross-disciplinary effort to

enhance protein secretion through both molecular biology and engineering concepts has been initiated. Protein secretion is affected by control of ion channels. Bioreactor operating strategies are used to separate growth and protein secretion and aid protein purification. Another effort is the use of T-cells for the production of useful biological substances. Lastly, a system's approach has been taken to identify bottlenecks such as end-product inhibition and devise strategies to increase product formation rate.

The second thrust area is focused on the "Engineering Principles in Protein Production". Following identification or construction of a cell line that efficiently combines the protein expression, processing and secretion, our next target is to provide an optimal environment for growth and production. Growth and product synthesis depend on many environmental factors, physical and chemical, which must be not only adequately identified and understood, but also quantitatively described for optimal bioreactor operation. Cell culturing procedures are extremely sensitive so that a good cell/protein manufacturing processes need to be closely monitored and controlled. Furthermore, much of the required knowledge may be qualitative or may reside dormant with the expertise of the practitioners; this necessitates the use of methodologies from the field of expert systems to achieve the best cell/bioreactor combination. These problems define our goals in "Engineering Principles in Protein Production", as well as our strategy in meeting these goals. Our overall objective is two-fold: first to elucidate the engineering principles through complete kinetic description of environmental effects and systems integration for the selection, design and operation of optimal bioreactor systems for protein production. Second, to develop, test and demonstrate with a variety of standard and new (recombinant and other) cell lines, conventional and novel bioreactor configurations for their feasibility and operational improvements. The use of several cell lines in the different phases of the program will insure the breadth and generic value of the results while continuous contact with the genetics and molecular biology effort will provide the necessary feedback for optimally structuring the desired cell-bioreactor combination. The specific research focus in this area includes both anchorage-dependent and anchorage-independent cells. Basic knowledge in fluid mechanics in bioreactors are being sought. Increased rates of operation are sought by increasing cell density by cell flocculation, novel entrapment matrices (ceramic monoliths and glass fibers) and environmental and genetic means to control and reduce end-product inhibition. Lastly, a systems' engineering approach includes the use of expert systems and intelligent sensors for monitor and control.

The third thrust area is focused on "Downstream Processing in Biotechnology", which is a major barrier in manufacturing of therapeutic proteins. Our efforts in downstream processing focus on improving current technology and developing new principles. To improve current technologies, we focus on problems with membrane processing. This includes electrical control of membrane permeability, rotary devices to induce secondary flow to minimize fouling, and development of continuous affinity recycle extraction (CARE). The focus on chromatography processes recognizes the importance of immunoadsorption and addresses the barriers of operation and scaling this technique. In addition, consideration is given to novel materials for adsorptive processes, including electrically conducting polymers and packed beds of fibers as an alternative to beads as a chromatographic matrix. We are developing new recovery technologies which include biphasic aqueous extraction and micelles for selective extraction of proteins. A major barrier in the recovery complex proteins is associated with efficient refolding of proteins during processing. We seek solutions to this problem through the use of reversed micelles as a medium for refolding, and new concepts of antibody-assisted refolding to catalytically enhance the rate and to stabilize properly folded molecules. Considerable attention is given to experimental verification of models for simulation

and design. These models are important for development of computer-aided design tools using both ASPEN PLUS for process simulation and expert systems for designing advanced recovery strategies.

INDUSTRIAL COLLABORATIONS AND TECHNOLOGY TRANSFER

Industrial collaborations and technology transfer are important goals of this Center. In 1986, our Industrial Consortium Program was established. In 1989, there is a total of 57 companies in this Program, representing the entire spectrum of the biotechnology industrial sectors. A large number of collaborative research projects were performed with our industrial partners. During 1988-1989, a total of 35 collaborative industrial projects were in place with an additional 11 industrially sponsored research projects. Lastly, during 1988-1989, there were 19 industrial scientists and engineers in residence at this Center.

To affect the timely and efficient transfer of technology, two separate offices have been established. The Technical Coordination Office handles the visits from companies, annual symposia and the special workshops. The Technology Transfer Office has established a data-base on all of the research projects within the Center and provides this information to the Industrial Consortium members. This Office also coordinates the dissemination of the recent research developments from the Center through presentations at company sites or on the MIT campus. The activities of the Technology Transfer Office of the Center are also closely coordinated with MIT Technology Licensing Office.

Special efforts are also made by this Center to disseminate information from its research programs. This year's Annual BPEC Symposium was held on October 18-19, 1988 and was accompanied by 325 attendees from 92 companies. In addition, two special workshops were held for the Industrial Consortium members. The workshop on "The Regulatory-Bioprocess Engineering Interface", was held in January, 1989 with a total of 130 attendees representing 47 companies. The second workshop entitled, "Bio-Instrumentation" was held in June, 1989 with a total of 40 attendees representing 17 companies.

A summary on some of the other achievements from the BPEC during 1988-1989 is tabulated below.

Publications	- 247
Presentations at Conferences and Symposia	- 121
Industrial Seminars	- 49
University Seminars	- 85
Theses	- 28
Company Visitors to BPEC	- 122

NEW APPOINTMENTS AND NEW INITIATIVES

Professor Martin L. Yarmush, Department of Chemical and Biochemical Engineering, Rutgers University, joined the Center in 1988. Professor Yarmush and his group are collaborating with this Center in research dealing with immuno-adsorption and antibody-assisted refolding of recombinant proteins.

Two new educational programs have been planned with the inputs from the BPEC during 1988. The first initiative is to implement the Interdepartmental Biotechnology Program. This will be an interdisciplinary pre-doctoral training program involving 13 faculty members from the Department of Biology, 11 faculty members from the Department of

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Chemistry, and 10 faculty members from the Department of Chemical Engineering. A Training Grant Proposal was submitted to the NIH (NIGMS) in January, 1989. This Program Director will be Professor Daniel I.C. Wang and the Associate Program Director will be Professor Philip A. Sharp. The NIGMS Training Grant Proposal is to solicit fellowships for trainees for the new interdepartmental initiative. The decision from NIGMS to support this Grant will be announced in September, 1989.

The second initiative by the BPEC is to establish a "Minority Internship Program". A proposal to the National Science Foundation has been submitted to support both faculty and student internships to perform research at this Center during the summer. Initial contacts have already been made with the Chemical Engineering Department of Howard University and the Biology and Chemistry Departments of the North Carolina State Agricultural and Technical University. The outcome on the financial support for this initiative from the National Science Foundation will be announced in September, 1989.

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. The Director is Dr. Shaoul Ezekiel, Professor of Aeronautics and Astronautics, and Electrical Engineering and Computer Science.

To achieve its objectives, CAES offers two types of educational programs, at the workplace and on-campus, for the practicing professional. For learners at the workplace, the Center provides studio-based and classroom-based video courses, as well as videotaped symposia 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 1988-89 academic year, 84 professionals participated in the Advanced Study Program, 28 from the United States and 56 from 18 other countries. These Fellows attended regular graduate and undergraduate subjects that suited their needs. In addition, many of them performed individualized studies guided by faculty members and several participated in ongoing research programs. Also, the Center sponsored several subjects that are of particular interest to the Fellows, such as Project Management and Management of Technological Change. These subjects are listed in the MIT course catalog and are, of course, open to MIT students. CAES in addition, offered informal evening classes in Modern Computer Methods and American Language and Culture.

The Fellows in the Advanced Study Program are provided with study offices, computer facilities, and a videotape library with viewing facilities. The summer of 1989 will be our first year of participation in Project Athena, with 6 workstations being added to the CAES computer facility. We also offer a weekly luncheon seminar at which the Fellows give brief presentations on their work. Center staff and faculty also make presentations at these seminars.

Video based educational programs include professionally-produced studio and classroom courses as well as videotaped symposia focusing on recent developments in MIT research. Video courses are used at the workplace by a broad spectrum of businesses, government agencies, and educational and training institutions to instruct their engineers, scientists, and managers.

All 1988-89 productions were produced in the new CAES professional-quality television studio which is housed in Building 9. Designed to meet the diverse needs of the Institute, the television studio complex has increased Center productivity, enhanced video production, and facilitated the application of new video technologies. New releases include: Image Processing and TV Coding by Professor William Schreiber, Analysis of Welded Structures by Professor Koichi Masubushi, Machinery Noise and Diagnostics by Professor Richard Lyon, and courses in progress include: Lasers and Optics for Applications by Professor Shaoul Ezekiel, Managing the Source of Innovation by Professor Eric Von Hippel, and The Taguchi Management Method by Professor Don Clausing. CAES video programs continue to be produced entirely by Center staff using Center-owned equipment.

In order to enhance the Institute's well established role in Continuing Education, CAES will be pursuing several new initiatives in educational programming to strengthen MIT's coupling to Industry, both local and out-of-state. These initiatives include the offering of credit-bearing regular MIT subjects on Saturdays, and non-credit one-day short programs also on Saturdays. In addition, the Center is also planning to offer one-day programs that will be transmitted by satellite to industrial and government sites nationwide.

The summer of 1989 will be the third year of participation in a unique initiative to provide continuing education for electrical engineering faculty in US colleges. Two-week intensive courses are offered by universities and industrial organizations. Faculty members numbering 228 from 144 colleges in 46 states will have participated in these first phases of the program. The topics vary from Artificial Intelligence to Digital Signal Processing. CAES plays a key role in the organization, coordination, and administration of this program under the aegis of the American Society for Engineering Education (ASEE). In the summer of 1989 four out of the 12 two-week courses will be offered at MIT.

MIT's Video Production Services, serving the Institute for over ten years, has been integrated into the Center and will continue to provide a full range of services for the Institute. Any video need can be taped efficiently and at a reasonable cost at any location or at CAES facilities. Services include, among others, a full-production television studio, a television classroom, videotaping on location, on and off-line editing, plus tape duplication.

SHAUL EZEKIEL

Center for Technology, Policy, and Industrial Development

This year the Center for Technology, Policy and Industrial Development (CTPID) completed its initial development plan which was adopted four years ago when the Center was established. Components of the plan were to organize a unit that would be concerned with the interface of societal issues involving technology and the policy-making process. The Center was designed to serve as a catalyst bringing together faculty and students with particular disciplinary skills to pursue interdisciplinary educational research and outreach activities. The principal educational activity is the Technology and Policy Program, a graduate program involving approximately 60 students. Two major research programs were inaugurated: the Hazardous Substances Management Program and the International Motor Vehicle Program. An outreach program was initiated to involve both public and private sectors in ongoing Center activities.

With the successful completion of the Phase I development plan, the Center focused this past year on a long-range planning process for Phase II development. In this phase, the immediate objective is to formulate a long-term intellectual agenda incorporating the specifics of plans for educational and research initiatives, the development of new program areas, human resource needs and funding possibilities, and an overall implementation plan to support these goals. Planning for Phase II has involved assessing the future of policy activities and planning the possible inclusion of more scholars, from MIT and elsewhere, and topical areas. These issues have been extensively discussed in meetings of the Center internal and external advisory boards.

As part of the planning process a mission statement for the Center was adopted:

To more effectively utilize science and technology in policy and decision making, focusing on problems of national and international importance, and to educate future leaders with dual competency in technology and policy; to perform a catalytic integrating role at MIT, building upon its unique science and technology resources, by providing a broad interdisciplinary perspective and increasing the policy impact of MIT departments' traditional educational and research activities.

Based on these principles, planning for the future of the Center is focusing on how to bring a wider range of MIT resources into technology policy dialogues. This second phase of planning is significant beyond the bounds of CTPID; it intimately links concerns of the Center to other parts of the Institute. In a year which has seen an upsurge of Institute-wide planning for the future of policy studies at MIT, the Center has provided a locus for this dialogue to evolve.

The long-range plan for CTPID emphasizes the need for developing an Institute-wide capability in science, technology, policy, and society that would focus on many of the critical national and international concerns in which decisions involving the use of technology and science will be fundamental, for example, environmental change at the global level; energy options for the future; the future of the infrastructure of the US; and the role of nations and resources in the international marketplace. The plan amplifies, and suggests ways to operationalize, the January 1989 mission statement of the School of Engineering which is "To prepare men and women, through education and research, for the imaginative, purposeful, and thoughtful creation and utilization of knowledge and technology designed to improve the human condition and maintain the diversity of life on Earth."

In 1988-1989, a wide range of new and on-going programs and projects, varying in size from single-scholar studies to major interdisciplinary efforts, were energetically pursued at CTPID. The objective uniting them is the need to utilize technology to further industrial development in a socially responsible manner. Over the four years of growth and change at CTPID, we note the evolution of a special emphasis on 1) internationalization of both the drivers and the effects of technologies; 2) the interconnected quality of the physical, economic, and social environments; and 3) the need for further adaptation of the decision-making processes available to policy makers in public and private sectors. This tripartite emphasis has shaped developments in the educational, research, and public service initiatives at the Center this year.

EDUCATION

In education, the Center supports the Technology and Policy Program (TPP) and the Chemicals in the Environment subject sequence. This year, TPP added a second track for students wishing to emphasize political, economic, and organizational aspects of technology and policy. The new curriculum is fully

integrated with the original program, and students will share the core Proseminars and requirements for basic subjects in technology and policy. Students will be admitted to the new concentration in the program through the Department of Political Science. Professor Michael Lipsky, of that department, has become Associate Chairman of the Program, assisting Professor Richard de Neufville, Chairman.

The sequence of courses, Chemicals in the Environment, developed by the Hazardous Substances Management Program (HSMP), now in its second year, has attracted a large group of students from several departments at MIT and other schools. The four courses, which may be taken separately or sequentially, give graduate and undergraduate students a core of integrated subjects enabling them to be effective in the area of hazardous substance management. The courses have been structured to provide a systematic and interdisciplinary look at the critical issues of chemicals introduced into the environment.

RESEARCH

Center research programs have gained the support of industry, government, labor, and public interest groups in the study of a wide-ranging group of issues. Some of this year's major developments are highlighted here.

The largest research program at the Center, the International Motor Vehicle Program (IMVP), has continued its on-going comparative studies of "best practice" in the industry. This year the program has emphasized investigations of the world-wide components industry, the challenges facing "new entrant" countries and companies, and the technology and policy implications of "smart vehicle/smart highways" in the US and Europe. Several new sponsors joined IMVP in 1988/89, including Peugeot SA, Volkswagen AG, and Daimler-Benz AG, the Republic of China (Taiwan), the Mexican Association of the Automotive Industry, and the National Autoparts Industry (of Mexico).

The Hazardous Substances Management Program (HSMP) gained two new sponsors this year, Amoco Corporation and BP America Inc. HSMP research now includes investigations of the incineration of hazardous waste; siting policy for disposal facilities; computer-supported negotiation; corporate environmental management policy; health effects of incineration; and groundwater contamination. In February 1989, MIT, Tufts, and the New Jersey Institute of Technology formed a consortium to establish a Hazardous Substances Research Center, part of a nationwide program sponsored by the US Environmental Protection Agency.

OUTREACH

Several meetings at MIT and abroad organized in cooperation with the Center brought together interested parties in technology and science policy-related areas. The Third IMVP International Policy Forum, held in Acapulco, Mexico in May 1989, focused on the future prospects for the world's components industry and an examination of the strategies and policies for the 1990s facing both the "new entrant" and "mature" motor vehicle-producing companies and countries. The Forum drew participants from many nations and the several sectors involved in auto production.

The Center and the Energy Laboratory cosponsored an ILP symposium on global change chaired by Dr. Malcolm A. Weiss of the Energy Lab. The most important element, and the focus of the symposium was greenhouse warming. The meeting was keynoted by Dr. Robert M. White '49, president of the National Academy of Engineering, who said that the need for effective international management of global change was "the quintessential challenge for mankind for the next century." Sessions involving speakers from MIT, other universities, and government and private agencies covered the components of change, climate modeling, the impacts of global change, and dealing with global environmental change. Participants emphasized that not all action needs to be international--local, regional, and national initiatives must be taken to combat the problem of greenhouse warming.

The Seventh Biannual Conference of the International Telecommunications Society was held at MIT in 1988. It was cohosted by the Center and Bellcore. The meeting drew about 300 people including participants from Belgium, Canada, France, Italy, Japan, Sweden, Switzerland, and the UK. The two-and-a-half day conference covered four major program areas: new technologies and new markets; the international dimension, that is the implications of "networks without boundaries"; future network architecture and design; and changing public and social policies for future network environments.

Policy analysis by researchers in the HSMP in the area of hazardous waste incineration led to a invitational conference at MIT in 1988. The meeting brought together a group of representatives of the various positions

that have been adopted toward the conflict over incineration. The objective of the meeting was to move toward consensus on the various issues to develop a model of how the gridlock over incineration might be broken. Program members acted as facilitators, rather than as proponents of any particular policy, at the conference which was conducted according to an innovative decision-making process for complex issues. Based on the findings at the meeting, which was subtitled "confronting the sources of disagreement", new materials for training incinerator operators have been developed by a leading industry group. Some of the findings of the incineration conference will be presented in a forthcoming special issue of *Environmental Impact Assessment Review*, a quarterly journal edited at the Center.

As CTPID moves into the next phase of its activities, its faculty and staff are working together not only to pursue the educational and research objectives established in Phase I, but also to contribute to the development of policy studies for science- and technology-intensive issues throughout the Institute.

DANIEL ROOS

Center for Transportation Studies

Introduction

The Center for Transportation Studies (CTS) is an interdepartmental organization whose objective is to provide an environment in which faculty, students, and staff can work together on transportation issues, many of which are interdisciplinary in nature. Programs of research, education, and industry outreach are supported in part by income from the Center's endowment which was graciously contributed by the UPS Foundation, in part by support from industrial and public sector sponsors, and in part by MIT. These three programs are closely related as we serve the needs of our students, participating faculty and staff, and the transportation industry.

The Center draws on the faculty and staff of MIT to provide programs of interdisciplinary research and education. The vitality of the Center depends on its ability to attract individuals representing a wide-ranging set of disciplines that can be applied to the transportation environment. We are fortunate in having over 50 faculty and staff representing all five schools affiliated with CTS. Departments represented are:

Aeronautics and Astronautics, Architecture, Civil Engineering, Economics, Electrical Engineering and Computer Science, Materials Science and Engineering, Mathematics, Mechanical Engineering, Ocean Engineering, Physics, Political Science, Urban Studies and Planning, and Sloan School of Management.

CTS Long Range Planning Activity

As with all other units in the School of Engineering, CTS was asked to develop a long range plan during this past year. We evolved the following mission statement as part of that process.

- The Mission of the Center for Transportation Studies is first, to identify critical issues in the field of transportation

and then,
- To develop interdepartmentally-based research, education, and outreach programs to address these issues by providing an effective environment for interested faculty, staff, and students.
- This mission explicitly includes the development of strong ties between CTS and both the public and private sectors of the transportation industry.
- Contributions to the transportation field in

Technology
Systems Analysis and Economics, and
Institutions and Management

are central to the mission of CTS.

The critical transportation issues we identified are as follows:

- **Congestion** - Likely to be the public policy issue of the 90's, we are experiencing urban, suburban, and air congestion of unprecedented intensity. This congestion impacts substantially on productivity (e.g., through the logistics cycle).
- **Infrastructure Deterioration** - Closely related to congestion, deteriorating infrastructure is causing capacity reduction on many transportation facilities. In addition, life cycle costs are out of control. What to do and how to fund it are critical public policy questions.
- **The Changing Face of the Transportation Industry** - The 1980's have seen dramatic changes in the transportation industry in the United States. New opportunities have arisen as a result of the Staggers Act and the Motor Carrier Act of 1980 (i.e., deregulation), the introduction of intermodalism on a large-scale, and a substantially restructured rail and trucking industry.
- All of the above relate to the international economic competition in which the U.S. finds itself. Congestion and infrastructure impact the ability of U.S. industry to effectively compete in a worldwide economy. The restructuring of the transportation industry needs to account for this competition as well. International implications are a major consideration as we build programs responsive to the challenges of the Pacific Rim and Europe/1992.

In our judgment, the above are among the major emerging issues in transportation. To address these issues we are actively pursuing four major research initiatives as follows:

- **Intelligent Vehicle Highway Technology.**
- **Infrastructure Analysis and Technology**
- **Logistics**
- **Information Systems**

Intelligent Vehicle Highway Technology (IVHT)

This initiative of CTS deals with congestion and safety and the use of advanced technologies in microelectronics, communications, sensing, controls, network theory, and other areas to enable the development of a new generation of more efficient, higher capacity, higher speed, safer highway systems. Professor Joseph Sussman is playing a major role on "Mobility 2000," a national steering committee developing a national program in this area, which met at MIT in April 1989.

CTS, working in cooperation with the Center for Technology, Policy, and Industrial Development, has initiated a multifaceted program in the area of intelligent vehicle highway technology, focusing on technology, systems analysis, economics, organizational and international issues. Areas such as advanced traffic management systems, advanced driver information systems, advanced vehicle control, network analysis and control, motorist information systems, intelligent vehicle systems, information technology applications, human factors, and system evaluation frameworks are being considered.

Infrastructure Analysis and Technology

Underinvestment in infrastructure and infrastructure deterioration is a fact of life in the United States. More than mere inconvenience, the infrastructure problem is having an impact on national productivity.

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CTS is working in the infrastructure area from several viewpoints. From a technology perspective, we are dealing with concrete bridge deck deterioration and detection techniques via in situ testing, new construction materials (e.g., ceramics), and robotics in construction and maintenance. In systems, we are concerned with theory and methods for analysis of infrastructure performance and maintenance strategies with life cycle costing for transportation facilities. Both highway and rail facilities are considered.

Our activities as leader of the New England Transportation Infrastructure Consortium, the Region One University Transportation Centers Program (see later section), and the AAR Affiliated Laboratory Program allows us to develop a substantial research agenda in this important area.

Logistics

Deregulation of the freight industry has enabled firms to take advantage of operations research methods and new computer technology to dramatically improve their logistic efficiency. It is estimated that distribution costs have dropped 20 percent since 1981, contributing to U.S. productivity and competitiveness. CTS faculty have been among the pioneers in developing practical computer-based planning systems for logistics operations. These applications cut across the boundaries of industrial/transportation engineering and business systems. CTS is developing joint educational and research programs in logistics involving engineering and Sloan School faculty and students. CTS will continue to support the efforts of MIT faculty in these areas with Professor Yosef Sheffi in a leadership role.

Programs are underway with the trucking industry and with the railroad industry, considering areas such as empty car distribution, rail maintenance policies, network operations, cargo ship routing and scheduling, truck routing and scheduling, and inventory control.

Information Systems

Part of the CTS mission is to utilize advanced technology to improve operations, design, planning, and maintenance in the transportation industry. Information systems represent an area in which extraordinary changes are taking place. The potential for this technology in the transportation industry, with its inherently geographically dispersed nature, is enormous.

Faculty and staff are developing a number of programs in this area, including the relation of organization structure to information systems, large-scale geographically distributed data bases, electronic data interchange, knowledge-based expert systems in transportation, computer-aided methods for air systems operations, and use of information technology to improve transportation systems operations.

Additional Programs

In addition to the initiatives discussed above, it is important to note and highlight other important ongoing transportation programs at CTS. CTS has provided support to these programs through seed funding, administration, and by providing an extensive set of external contacts. These include: urban transportation, air transportation, ocean transportation, rail operations and vehicle technology, and vehicle crashworthiness optimization.

Research

Research in transportation is approached through many disciplines at many different levels, and involves all modes of transportation, both passenger and freight, in both the public and private sectors. During the past academic year, 116 sponsored, seed, and unsponsored projects

were listed in the Center's Current Research Projects in Transportation at MIT (available upon request), 44 of which had been initiated within the past year. Also, within that year, the number of faculty researchers involved in transportation studies grew by 20 percent. Categories of research are as follows:

- Logistics and Network Analysis
- Rail and Trucking
- Air Transportation
- Computer Systems
- Motor Vehicles
- Health and Safety
- Ocean Transportation
- Urban and Regional Transportation Planning
- Labor Issues
- Infrastructure Maintenance and Rehabilitation

Annual sponsored research volume for the Center continued at the healthy level of \$2.0 million.

University Transportation Centers Program

Last fall, MIT was designated as one of ten universities to take the lead in establishing a four-year, \$40 million grants-matching program for the U.S. Department of Transportation.

Intended to provide a national resource for research and training in both passenger and freight transportation, the DOT's new University Transportation Centers Program (UTC) is designed to attract the nation's best talent to the study of transportation by establishing one university transportation center in each of the ten standard Federal regions.

Under the directorship of Mr. Thomas Humphrey, Principal Research Engineer at the Center for Transportation Studies, MIT acts as lead university for Region One, which includes the Universities of Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont, Harvard University, and North Carolina Agricultural & Technical State University.

In keeping with the broad-based mission of CTS, the program for the first year focused on the three theme areas--technology, systems analysis and institutional policy analysis. First-year technology projects at MIT are Prediction and Measurement of Corrosion-Induced Cracking in Reinforced Concrete, Professor Victor Li and Dr. Kenneth Maser; and Structural Applications of Polymer Composites in Transportation Facilities, Professor S. Shyam Sunder. Systems analysis projects are Use of Information Technology for Improving Traffic Flows, Professor Haris Koutsopoulos; and Network Design and Transportation Planning, Professor Thomas Magnanti. The institutional and policy analysis project is Improving Transportation Workforce Management Methods in the Transit Industry, Professor Nigel Wilson.

Education

MIT offers advanced degrees in various areas of transportation at the masters and doctoral levels. Almost 100 subjects are offered in transportation and related fields including systems methodology, operations research, social science, and management. Over 50 students are currently working toward masters or doctorate degrees.

The Center administers the interdepartmental Master of Science in Transportation program. Its graduates have gone on to careers with carriers, operating agencies, shippers, consulting firms, and government, and into doctoral programs at MIT or elsewhere. Students in the MST program take core subjects in transportation systems analysis and transportation economics. Then, concentration in areas such as logistics, urban transportation, air transportation, ocean transportation, etc., are available. Professor Nigel Wilson chairs the MST Program.

Of all the graduates MIT has sent forth in recent years to work in the transportation field, we find an impressive number have chosen to make at least part of their contribution through training the next generation. Nearly 20 percent of the students who studied transportation here are now teaching in transportation programs at schools around the world, including many of the most highly-regarded schools in the transportation field.

Two distinguished visitors, Professor Anna Nagurney from the University of Massachusetts and Professor Sergio Jara-Diaz from the University of Chile gave advanced subjects in Network Analysis and Advanced Topics in Transportation Economics, respectively.

In an effort to reach undergraduates who might be interested in graduate study, but who have not yet had the chance to get acquainted with the transportation field, this year, for the second year, the Center funded six undergraduate research fellowships. Through these, MIT undergraduates work with faculty and staff on transportation research projects.

United Parcel Service (UPS) Fellowships

CTS continues to provide fellowship support funded by the UPS Foundation, for particularly able students at the MST and doctoral levels. In 1988/89, we split the UPS award between Rina Rotshild and Takayuki Morikawa and made a special half fellowship award to Jonathan Richmond. An MST fellowship was also awarded to Theodore Botimer.

We also continued to provide partial support for other needy graduate students in transportation.

INDUSTRY AFFILIATE ACTIVITIES

The CTS Industry Affiliates Program, established in 1981 to develop relationships between MIT and the transportation industry, is an important component of the education and research programs of the Center. The program is under the direction of Mr. Gerard McCullough, Deputy Director of the Center. The members are: American President Lines, Burlington Northern Railroad, Campbell Soup, Conrail Corporation, CSX Transportation, Digital Equipment, Dow Chemical Company, DuPont, Federal Express, General Motors Research Laboratories, Gillette, IBM, Johnson and Johnson, The 3M Company, Maersk Lines, Inc., Nabisco Brands, Norfolk Southern, Rockwell International, Ryder System, Sea-Land, Southern Pacific Transportation, Union Pacific, and United Parcel Service.

The success of the Affiliates Program has helped to give the MIT Center for Transportation Studies a unique place among the dozen or so research centers in transportation at American universities. The program has provided important opportunities for MIT faculty and students. Since 1985, the Affiliates Program has attracted top leaders in transportation to high level forums to discuss emerging policy issues in transportation. These forums give the faculty access to transportation decision-makers at the highest level. In addition to these senior level forums, many mid-level executives have been attracted to MIT to participate in technical seminars, clinics, and summer subjects developed by the Affiliates Program. These events give MIT faculty a chance to work with transportation executives on real world problems. The Affiliates Program has opened up to faculty and students at MIT a research domain in transportation and logistics whose problems are meaningful, complex, and intellectually challenging.

In keeping with the goals of the program, each year an affiliate firm hosts a day-long meeting for the others on a subject of mutual concern. This past December, approximately 50 senior executives of shipper and carrier organizations convened at Ryder Systems, Inc., to focus on **New Dimensions in Transportation Partnering.** We focused on partnering in transportation because there is a growing recognition that "partnership" is essential in getting the most from transportation logistics, but that "partnering" is a widely-used term that is hard to measure. The meeting provided participants with the opportunity to meet with other senior executives from a range of industries to discuss the value of partnership and how best to achieve it. Professor John Henderson of the Sloan School of Management gave the keynote address dealing with his research in the area.

Next year's meeting will be co-hosted by American President Lines and Southern Pacific Transportation.

Summer Executive Program

Last year, for the fifth consecutive year, an intensive one-week seminar taught by Professor Sheffi was held on **Logistics Analysis for Carriers and Shippers.** The seminar was designed to help shippers become increasingly sophisticated about logistics, and to help carriers better understand demands by shippers which are based on logistics analysis. Attendance, as in the past, was limited to 28 so as to insure appropriate hands-on experience and interaction.

In June, the Executive Program in Transportation offered a new course on **Strategic Management.** The two-day course treated the design and implementation of business strategies in markets where firms are highly interdependent with their customers. Its focus was on transportation and distribution where carriers and shippers now work very closely together under long-term partnership contracts. Among the topics covered are the growing economic trend toward business partnerships, the elements of successful partnerships (including the technological requirements), the projected effect of government regulation on partnerships, and the implications of partnerships for labor/management strategies. It is anticipated this course will alternate in future years with **Logistics Analysis for Carriers and Shippers.**

Technical Seminars

The Industry Affiliates Program sponsors one- to two-day technical seminars for member firms. Among those offered this past year was a day-long working session on the **Integration of Information Systems.** The seminar was conducted by Stuart Madnick, Professor of Management Science, and Dr. Amar Gupta, Principal Research Associate, both at the Sloan School of Management.

The motivation for this meeting was that there are a growing number of situations in transportation and distribution that require the integration of information systems. When a firm begins to connect its information systems to those of its various customers, the complexity escalates quickly. At the same time, the proliferation of different kinds of information systems has created the need for new techniques to facilitate communication between them. Professor Madnick's and Dr. Gupta's research has revealed a complex set of issues requiring consideration when connecting different systems. To heighten consciousness of these problems and to suggest solutions, formal presentations were made at the meeting by Professor Madnick and Dr. Gupta on their research findings, followed with reports from the field by information systems experts at nine different organizations.

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Last spring, a two-day seminar on "Uncertainty and Transportation" was offered to affiliates. Chaired by Professor Amedeo Odoni, the seminar focused on mathematical methods for dealing with uncertainty in transportation operations.

The Transportation Computing Lab (TCL)

Under the direction of Professor Sheffi, the Transportation Computing Lab is the cornerstone of computing at CTS, supporting a high level of academic and research work. The Lab supports all transportation subjects and the individual research and academic work of graduate and undergraduate students in transportation.

During 1988/89, the Lab has continued to upgrade its hardware and expand its software library. We have now completed upgrading all the 8088-based machines to AT class and better. This was accomplished by purchases of new 286 machines as well as accelerator boards that were installed into existing machines. In addition, we purchased two more Everex Step 386 machines (one with a 386 math co-processor). Thus, the Lab now provides four 386 CPU's: the two Everex machines, one 386, and an IBM PS/2 Model 80. All of them operate at 20 MH.

In addition to upgrading the CPU's, we have upgraded our word processing capabilities by installing a high speed HP printer. This printer was networked to seven of the machines in the Lab with a memory box that allows queuing of jobs. We have also purchased an Apple Laser printer. This gives students the ability to do high quality final output.

On the software side, we have followed up with recent upgrades of all major packages that the Lab supports. In addition, we have acquired recent upgrades to all the compilers that the Lab supports and have extended the list of supported compilers. We have also purchased new statistical packages (CAD, AI Shells) and programming tool kits.

A variety of applications in logistics, demand modeling, infrastructure, and other areas, have been developed at the Lab for use in both educational and research programs. Certainly, the demand for the facility outstrips our ability to supply service. We interpret this as a sign of the vigor of our research and educational programs.

SPECIAL EVENTS

This June, the Center joined with the UPS Foundation to help support a two-day meeting in Boston on electronic data interchange, sponsored by the Transportation Research Forum. The conference focused on the managerial, institutional, legal, and technical issues, in order to help both large and small companies work together toward successful implementation or expansion of EDI.

Each year, CTS hosts many visiting groups interested in the transportation field. Worthy of special note is the visit in early May of members of the British House of Commons Select Committee on Transport, Mr. Jack Aspinwall, Mrs. Gwyneth Dunwoody, Mr. Peter Fry, and Mr. David Gilroy-Bevan. Dean Jack Kerrebrock, Professor Sussman, Professor Steven Lerman, Professor Karen Polenske, Mr. Humphrey, and Mr. Michael Markow spent a stimulating morning with these distinguished visitors discussing intelligent vehicle highway systems, infrastructure finance, and regional planning issues.

Luncheon Seminar Series

Every year, the Center sponsors this series featuring transportation experts from the public and private sectors, and from academia, discussing current issues in the transportation field. Open

to the public-at-large, the seminars draw an audience made up of students and faculty from the Institute, and the local business, government and academic communities. A broad spectrum of topics were covered by a distinguished group of speakers as follows: Mr. Robert Albee, Massachusetts Department of Public Works; Mr. James Keebler, Digital Equipment Corporation; Major General John H. Stanford, U.S. Army, Commander, Military Traffic Management Command; Mr. Howard P. Benn, New York City Transit Authority; Mr. Michael Fisher, Federal Express; Commissioner Richard A. Dimino, Boston Transportation Department; Mr. Lyle Saxton, Federal Highway Administration; Dr. Bernard Guyer, Director, New England Injury Prevention Research Center, Harvard School of Public Health, and Dr. John D. Graham, Deputy Director, New England Injury Prevention Research Center, Harvard School of Public Health.

Summer Subjects

Last August, for the sixth consecutive year, a one-week summer course was offered by Professor Nigel Wilson in **Public Transportation Service and Operations Planning** and attracted an international audience.

In June, Professor Richard deNeufville and Professor Odoni offered a new subject in "Airport Systems: Strategic Planning and Detailed Design." It proved very attractive to the professional community with 45 attendees from the U.S. and abroad.

The transportation world continues to be an exciting and challenging environment in which to work. Issues such as urban, suburban, air congestion, and infrastructure decay are having critical impacts on quality of life, national productivity, and international competitiveness. Changes in government-private industry relations, dramatic changes in a variety of technological areas and developments in international markets make the world of transportation a particularly dynamic theatre. With its multi-disciplinary faculty, CTS looks forward to contributing to addressing the critical transportation questions of the 1990's.

JOSEPH M. SUSSMAN

Laboratory for Computer Science

The MIT Laboratory for Computer Science (LCS) is an interdepartmental laboratory whose principal goal is research in computer science and engineering.

Founded as Project MAC in 1963, the Laboratory developed one of the world's earliest time-shared computer systems. This early research on the Compatible Time Sharing System (CTSS) and its successor MULTICS made possible innovative developments such as the writing of operating systems in high level programming languages, virtual memory, tree directories, on-line scheduling algorithms, line and page editors, secure operating systems, concepts and techniques for access control, computer-aided design, and two of the earliest computer games -- space wars and computer chess.

These early developments laid the foundation for the Laboratory's work in the 1970's on knowledge based systems -- for example, the MACSYMA program for symbolic mathematics -- natural language understanding, and (with BBN) the development and use of packet networks. During this same period, the Laboratory developed theoretical results in complexity theory and linked cryptography to computer science through concepts and algorithms for public encryption (RSA). In the late 1970's, Project MAC, renamed as the Laboratory for Computer Science (LCS), embarked on research in clinical decision making, the exploration of cellular automata at the borderline between physics and computation, and on the social impact of computers. At the same time, it began two major research programs in distributed systems and languages and in parallel systems. These led to the notion of data abstractions and the CLU language, the ARGUS distributed system, the dataflow principle and associated languages and architectures of parallel systems, local area ring networks, program specification and workstation development, where the Laboratory contributed the earliest UNIX ports and compilers, and the Nubus architecture, now used in commercial computers like Apple's Macintosh II.

The Laboratory's current research falls into four principal categories: Parallel Systems; Systems, Languages, and Networks; Intelligent Systems; and Theory. The principal technical goals and expected consequences in each of these four categories are as follows:

In *Parallel Systems*, we strive to harness the power and economy of numerous processors working on the same task. Research in the area involves the analysis and construction of various hardware architectures and programming languages that yield, over a broad set of applications, cost-performance improvements of several orders of magnitude relative to single processors. This research is expected to affect most of tomorrow's machines which we expect to be of the multiprocessor variety -- not only because of potential cost performance benefits, but also because of the natural, yet unexploited, concurrence that characterizes contemporary and prospective applications from business to sensory computing.

In *Systems, Languages and Networks*, our objective is to provide the concepts, methods, and environments that will enable heterogeneous computers, each working on different tasks, to communicate efficiently, conveniently, and reliably with each other in order to exchange information needed and supplied by their respective programs. Such communication may involve, beyond conventional electronic mail and file transfer, the calling of programs in one environment from programs in another, perhaps different, environment, and the sharing of structured data among such programs. This research is also expected to have a broad impact on future systems because virtually every machine will be connected to some network.

Taken together, these two thrusts in parallel and networked machines signal our expectation that future computer systems will consist of multiprocessors interconnected by local and long haul networks, and perhaps some day by national network infrastructures as ubiquitous and as important as today's telephone and highway infrastructures.

In the *Intelligent Systems* area, our technical goals are to understand and construct programs and machines that have greater and more useful sensory and cognitive capabilities. Examples include the understanding of spoken messages, systems that can learn from practice rather than by being explicitly programmed, and programs that reason about clinical issues and help in clinical decision making. We expect tomorrow's intelligent systems to be easier to use than today's programs across a broad front of applications, for the same reason that intelligent human assistants are more useful and easier to interact with than less intelligent ones.

In our fourth category of research, *Theory*, we strive to understand and discover the fundamental forces, rules, and limits of computer science. Theoretical work permeates many of our research efforts in the other three areas, for example, in the pursuit of parallel algorithms and in the study of fundamental properties of idealized parallel architectures and computer networks. Theory also touches on several predominantly abstract areas, like the logic of programs, the inherent complexity of computations, and the use of cryptography and randomness to the formal characterization of knowledge. The impact of theoretical computer science upon our world is expected to continue its past record of improving our understanding of and helping us to pursue new frontiers with new models, concepts methods, and algorithms.

1988 marked the 25th Anniversary of our Laboratory. This occasion was celebrated with a two day symposium on current research for an international audience of some 1000 people and a testimonial banquet attended by over 1200 members and guests of both the LCS and AI laboratories. Chaired by Professor Albert R. Meyer, the celebration was memorable and successful.

Research highlights during the reporting period were as follows:

1. Dr. Victor Zue and his research group moved from MIT's Research Laboratory of Electronics to LCS. This move promises to be significant for both the speech research effort and for other LCS groups through the potential synergism between speech research and computer architecture.
2. We have concluded a major agreement with Motorola to build the Dataflow machine, conceived and designed by the Laboratory's Computation Structures Group. This effort is significant for it represents the first major test of this new architecture invented by our Laboratory.
3. A new group, the Computer Architecture Group, has been formed and includes Professors Anant Agarwal, William Dally, and Stephen Ward, and their students and staff. This large group of computer architects plans to embark on a new project, NuMesh. The NuMesh involves an interconnection and intercommunication standard that goes beyond the notion of a computer bus to three-dimensional structures. As currently envisioned, the NuMesh will consist of small cubes (about 2cm. on the side) which will be able to plug together with other similar cubes at all six of their sides. Each cube will contain processing and communication chips. We envision that users of this technology will first construct in tinker-toy fashion a special purpose

aggregate that is best suited to their problems, and will then run these problems on the so-constructed machine. This approach is expected to make possible the benefits of special purpose computation out of general purpose subsystems. We are planning to fund this research out of an industrial consortium of manufacturers.

During 1988-89, the Laboratory continued its successful Distinguished Lecturer Series with presentations by David L. Parnas, Professor of Computing and Information Science of Queen's University; David S. Johnson, Department Head, Mathematical Foundations of Computing of AT&T Bell Laboratories; Raj Reddy, Director of the Robotics Institute of Carnegie Mellon University; and Robert W. Taylor, Director, Systems Research Center, Digital Equipment Corporation.

During this reporting period, Professor David L. Tennenhouse joined the Advanced Network Architecture Group; and Drs. Gregory Papadopoulos and Gill Pratt became Research Associates in Computation Structures and the newly formed Computer Architectures Group, respectively. Dr. Victor Zue and his Spoken Language Systems Group, including 4 research scientists, 15 students, 2 visitors, and 2 support staff, also joined the Laboratory. Two staff accountants, Ms. Azi Djazani and Mr. David Ruble joined the LCS administrative staff, and Ms. Mary Mitchell joined MIT and LCS as Administrative Officer, replacing Ms. Patricia Musa.

During the same period, Professor Robert H. Halstead left the Laboratory to join Digital Equipment Corporation. The students and staff of his research group have been reassigned to other Laboratory groups.

The Laboratory is organized into 18 research groups, an administrative unit, and a computer service support unit. The Laboratory's membership includes a total of 350 people -- 105 faculty and research staff, 35 visitors, affiliates, and postdoctoral associates, 30 support staff, 125 graduate students, and 55 undergraduate students. The academic affiliation of most of the Laboratory's faculty and students is with the Department of Electrical Engineering and Computer Science (EECS).

The Laboratory's funding comes predominantly from the U.S. Government's Defense Advanced Research Projects Agency, which accounts for about half of the total. The Laboratory is also funded by and has extensive links with industrial organizations. These include partnerships for the construction of major hardware systems, consortia

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for the development and maintenance of standards, like X Windows, and joint studies on research areas of common concern.

Technical results of our research in 1988-89 were disseminated through publications in the technical literature, through Technical Reports, numbers 426 through 451, and Technical Memoranda, numbers 363 through 406.

MICHAEL L. DERTOUZOS

Laboratory for Electromagnetic and Electronic Systems

The Laboratory for Electromagnetic and Electronic Systems (LEES) is a coalition of 12 faculty and 10 research staff from the departments of Electrical Engineering and Computer Science and Mechanical Engineering. Disciplines represented include power electronics, automatic control, electromagnetics, continuum electromechanics, high voltage research, heat transfer, insulation research, quantitative physiology, cell biology, systems analysis, and economics. Faculty and students collaborate in projects aimed at both the practical engineering objectives of sponsors and at the underlying engineering sciences. Interactions with other laboratories is encouraged including the Energy Laboratory's Electric Utilities Program.

POWER ELECTRONICS

Professors J.G. Kassakian, G.C. Verghese, and M.F. Schlecht continue to lead the Laboratory's teaching and research activities in power electronics. They have also assumed new professional society responsibilities, Professor Kassakian as a member of the Governing Board of the European Power Electronics Society, Professor Verghese as a member of the IEEE Power Electronics Society Administrative Committee, and Professor Schlecht as Chairman of the 1991 Power Electronics Specialists Conference.

The Summer Session offering, 6.33s, Introduction to Power Electronics, was again a successful enterprise. A workshop for industry, Hybrid Fabrication of Power Electronic Systems, was held under the auspices of the MIT/Industry Power Electronics Collegium, which continues to be a source of support and guidance for the Laboratory.

The component and manufacturing technologies that made possible the fabrication of 50 W, 100 W/in³ power supplies have been extended to higher power levels. A 250 W, 300/50 V converter using packaged surface mount components, and a 100 W, 50/5 V converter using unpackaged die and wire bonding have been built on ceramic substrates. These prototypes include all control and protection features necessary for practical applications. These converters have been demonstrated to the industrial sponsors of this work, and plans are being made to incorporate them into products for evaluation. The distributed power supply architecture made possible by such compact, high performance converters permits the consideration of radical changes in the physical configuration of computers, changes that have the potential to decrease product design cycle time, increase reliability, and decrease cost.

A major new program has been started in the area of EMI. This work integrates the developments previously made in the hybrid fabrication of power circuits with the Laboratory's unique active filter designs to create systems meeting the strict interference requirements of many applications. An important goal of this work is to understand the influence of control, component design, and circuit fabrication on the generation and reduction of EMI.

Continuing studies by Professor Verghese and his students, directed at dynamic modeling and control of power circuits and the development of corresponding computer based tools, have led to corrections of long-standing models of switched power converters. Simple approximate models that are well suited to sampled-data control of these converters have also been developed. In addition, novel schemes to permit decoupled control design and application for multi-switch, multi-output power converters have been obtained. The program continues in close collaboration with industry.

SYSTEMS IDENTIFICATION AND CONTROL

The possibility of speed and parameter tracking in induction machines, based entirely on measurements of stator voltages and currents, has been demonstrated by Professor Verghese and his students, working in collaboration with a group at the Technical University of Berlin. An experimental facility in Berlin, which was set up for parameter estimation studies aimed at detecting machine failures during factory testing, was modified to provide the data needed for MIT's studies. Short-term visits of graduate students in each direction were crucial to the success of the collaboration.

Failure detection based on parameter estimation is being studied by Professor J.H. Lang and Dr. S.D. Umans, again in the context of induction machines.

In collaboration with Professor S.D. Senturia of the Microfabrication Center, Professor Lang has continued the development of variable-capacitance micromotors. Using standard integrated circuit materials and equipment, surface micro-machining techniques have been developed for generating pancake motors (two micrometers thick, 100 micrometer diameter rotors) in silicon. Recently, these motors have been driven electrostatically at over 500 rpm in initial tests. Other microfabricated actuators are also under development, in particular for biological research. A microfabricated electrohydrodynamic pump, successfully demonstrated pumping and is currently being characterized.

Professors Lang and Verghese have been invited to present their accumulated experience on adaptive estimation of states and parameters for electrical machines as a keynote paper at the Second International IEEE Workshop on Microcomputer Control of Electric Drives, held in Trieste this July.

The MITEE Mouse is a robot that can compete with other "mice" for the shortest time to negotiate a maze. Under the direction of Mr. D.M. Otten, a series of these has been the basis for honing student, staff and faculty expertise in the design of systems combining electromechanics with sensor, power and microprocessor electronics and software. During this past year, MITEE Mouse three has competed in five contests from Tokyo to London, claiming three first prizes, a second and a third.

ELECTROMECHANICS, HEAT-TRANSFER AND CRYOGENICS

The experimental activity on the 10 MVA superconducting generator, carried out by Professors J.L. Smith, J.L. Kirtley and G.L. Wilson and Dr. S.D. Umans, continues to focus on a cryogenic problem. During the past year an understanding of that problem has developed and a "fix" has been proposed. The problem is that even a small heat leak at the liquid cryogen transfer stage produces vapor which fills two of the rotor reservoirs, blocking further transfer of liquid. The "fix" is to build an additional vent channel to remove the excess vapor. Further experimentation has shown that the thermal isolation system of the rotor is indeed performing well. At the present time, a final report on the project is in preparation.

Further evaluation of the use of "high T_c " superconductors in generators has been carried out by Professors Smith and Kirtley and Dr. Umans. An improved design program has been written and is being used to investigate the effects of increased operating temperature. At this time, it appears that the conclusions of the preliminary study will remain unchanged. High temperature superconductors will have to demonstrate much higher current density before they are useful in electric machinery. An article on this will appear in the November, 1989, Proceedings of the IEEE.

Professor Kirtley has been investigating issues related to electric power and electric propulsion for the United States Navy. During the past year, a simulation program for electric power distribution aboard ships was written. This can simulate the whole system, from generators to loads, and will be useful for looking at large scale transients associated with various generation schemes. The applicability of electric propulsion to nuclear submarines was investigated. The scheme assumed, involving a high speed generator and low speed or geared motors driving a conventional propeller, was found to be only marginally useful.

CONTINUUM ELECTROMECHANICS

In an EPRI sponsored project co-supervised by Professors M. Zahn and J.R. Melcher, electrokinetic effects on flow electrification are being studied. Electrification in systems where flowing highly insulating liquids may also function to insulate and cool equipment is being recognized as a primary limitation on the design of higher performance apparatus in applications that range from power apparatus to automotive fuel systems. This is especially so during a period in which polymeric materials are replacing metals in the transportation industry.

The "Absolute Charge Sensor (ACS) initially developed last year for measurements of flow electrification in such systems as electric power apparatus and automobile fuel pumps has been extensively improved. A U.S. Patent covering all claims has been allowed. Numerous ACS systems have been fabricated for use of EPRI contractors for electrification measurements in operating transformers and in oil flow loops for manufacturer testing of individual transformer components. A similar project funded by an automobile manufacturer is developing the ACS and related instrumentation for dealing with flow electrification of gasoline in polymeric fuel systems.

A flow facility with temperature and moisture control has been built for laboratory electrification measurements integrated with dielectrometry modules for monitoring moisture in oil and paper using micro and macro interdigital sensors. Measurements using this flow facility have shown a strong dependence of electrification on temperature and moisture levels in oil and pressboard, including charge polarity reversals. These observations have stimulated an effort to distinguish the roles of temperature and mass transport in the electrification process. Improved modeling analysis with parameter estimation of the "chemical equilibrium" charge density at a solid/oil interface, of the injected charge density under high voltage energization conditions, and of the charge diffusion coefficient in the fluid sub-layer near the wall, is in useful agreement with MIT measurements. More complete computer modeling of charge conservation relations of bipolar ions including charge generation, recombination, migration, and diffusion in the face of turbulent flow is providing further understanding of the electrification process and is the first step towards incorporating electrochemical kinetics.

HIGH VOLTAGE AND INSULATION RESEARCH

Under the directions of Professor M. Zahn, sensitive Kerr electro-optic field and space charge mapping measurements have been successfully achieved in the weakly birefringent dielectrics of transformer oil, silicone oil, melted low density polyethylene (PE), and liquid nitrogen. Measurements in PE, transformer oil, and silicone oil have shown strong space charge effects that significantly distort the electric field distribution and affect the voltage breakdown strength. Liquid nitrogen has not shown significant space charge effects.

An expert optical multichannel analyzer system has also been completed which allows high sensitivity and computer automated data acquisition and processing of Kerr effect

measurements. It is hoped that more accurate field and charge density measurements at electrode interfaces will help in understanding charge injection physics.

A number of years ago, Professor Melcher and his students were the first to demonstrate the pumping of homogeneous isothermal dielectric fluids subjected to a traveling wave electric field in such a way as to implicate charge separation at the conduit walls. Through methodical experimentation and correlation of observations with a mathematical model, a student supervised by Professor Zahn has now been able to elucidate the dependence of this phenomena on charge injection at the conduit wall. The experiments, for liquid Freon, transformer oil, and silicone oil, established the role of applied voltage amplitude and frequency, fluid conductivity, and fluid viscosity. Reverse pumping, where the fluid is displaced in the direction opposite to the traveling wave direction, occurs when the ratio of voltage to frequency is small, but switches to forward pumping when the ratio is large. This phenomena is successfully described by the model, which is then used with ACS measurements to discriminate between the influence of additives on the bulk charge relaxation and charge injection.

Over the past five years, under Electric Utility Program sponsorship, the LEES has been engaged in a program to develop advanced technologies for improved reliable monitoring to detect hazardous internal conditions in large power transformers while in service. There have been two separate categories of research effort in the program: 1) the development of improved sensing of fluid, high voltage, and vibration phenomena important to transformer monitoring; and 2) the development of analytic structures that incorporate data and sensor validity checking, hypothesis/trend checking, and decision algorithms to advise operating personnel of the transformer status.

The past years developmental phase has been led by Mr. W.H. Hagman. The work has involved substantial experimentation, theoretical analysis, and development of practical model tools and analytical structures for the measurement and interpretation of sensor signals. The experimental work has involved bench tests on small test fixtures to demonstrate principles, and trial studies of hardware and software on an on-line 50 kVA pilot facility transformer.

The sensing studies have included novel and potentially effective new on-line technologies such as solid-state fluid contaminant detection (Professor Melcher), vibration signature analysis for the purpose of detecting mechanical changes (Mr. Hagman and Professor Kirtley), and dielectric strength testing of the oil insulation (Dr. C.M. Cooke).

In addition to major new sensing methods, the program has pioneered the application of modern analysis procedures to extract reliable information about the status of the transformer. In particular, it is recognized that the analysis structure must compensate and adjust for the normal life cycle operation of the transformer and still detect when significant internal changes have occurred. Another important attribute of the MIT approach is the use of multiple characteristics which are regularly measured and analyzed. Here the objective is to improve recognition of true internal changes and to provide better identification of hazardous conditions.

Successful, long term operating experience with the MIT Pilot Test Facility in this Year 5 of the project has expedited progress toward useful trend analysis. Present and future work includes: implementation of bad data/sensor detection, and measurement and parameter residual detection - though the use of thresholds, pattern matching, and an expert system; coupled with diagnosis of the transformer's condition through the use of an expert system and knowledge base derived from historical literature, present transformer experts, and laboratory experiments.

The MIT group's other major effort during Year 5 has been in transfer of technology to an industrial team charged with producing a field-deployable Transformer Performance Analysis System (TPAS) which will be tested on full-scale power transformers. The utility consortium which supported the prior years' research at MIT is currently funding J.W. Harley, Inc. and Westinghouse Electric Corporation, and MIT (under subcontract to Harley) is assisting in the TPAS system logical development, using the existing MIT system as a framework.

In connection with the Transformer Pilot Facility, Dr. Cooke and Mr. Hagman have completed an effort to improve methods of interpreting measurements of dissolved gas-in-oil using a commercial instrument based on the Hydran technique. A new program with the manufacturer has resulted, to translate these results into improvements on the commercial instrument.

An electro-acoustic technique for monitoring charge accumulation in solid dielectric cables has been given a preliminary successful demonstration by Dr. Cooke and his students. The approach is non-destructive, resolving the distribution of charge within a broad range of materials. Electromechanical coupling to the space charge distribution created by an impulse in applied field excites an acoustic wave. This wave is detected at the exterior surface of the dielectric and processed to display the internal charges. Work to improve the resolution and signal-to-noise level and to exploit the techniques in understanding the behavior of conventional and new insulation materials continues.

BIOLOGICAL ELECTROMECHANICS AND PHYSIOLOGY

Professor A.J. Grodzinsky and his group have been studying the effects of physical forces on the growth, remodeling and repair of cartilage. A recent initiative has shown that cartilage cells cultured in agarose gel over 4-8 weeks synthesize a mechanically functional cartilage-like tissue. Cell/gel disks have significantly enhanced mechanical stiffness and streaming potential response with increasing time in culture, properties that constitute a fingerprint of normal cartilage behavior. This system is now being explored as a possible cartilage replacement material, and as an indicator of the mechanisms by which connective tissue cells respond to physiological loading forces.

Experiments using native cartilage in organ culture have led to the recent discovery of several mechanisms by which static compression can lead to degeneration of cartilage, consistent with clinical observations of cartilage degradation due to joint immobilization. Static compression not only reduces synthesis of new matrix molecules, but retards the proper assembly and maturation of complex proteoglycan aggregates, the molecules responsible for cartilage's compressive stiffness. In addition, low frequency compression produces increased loss and degradation of tissue proteoglycan and protein constituents. These responses mimic osteoarthritic-like degeneration of cartilage, and may help in understanding the physical mechanisms that underly cellular behavior. New initiatives between Professor Grodzinsky's group and the Department of Orthopaedics, Massachusetts General Hospital are aimed at discovering the role of mechanical loading and physicochemical forces in cartilage in the synthesis of anabolic growth factors and catabolic proteases that may play crucial roles in regulating cartilage metabolism and degradation in osteoarthritis.

Professor Grodzinsky is also continuing research on electrically controlled membranes for protein separations and feedback-regulated drug delivery. A recent publication in Chem. Eng. Sci. and a patent application focus on mechanisms and implementation of processes for controlling protein flux across hydrogel membranes, including electric field modulation of membrane pore size, and electrophoretic and electroosmotic argumentation of protein flux. New applications of these processes in biotechnology now being explored are the possibility of electrical enhancement of nutrient diffusion to cultured cells immobilized in hydrogels,

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and enhancement of the transport and recovery of desired cell synthetic products (e.g., drugs) during culture.

Professor R.C. Lee and group have been investigating the role of transmembrane calcium currents in the control of biosynthetic responses of fibroblasts. This work is motivated by interest in the underlying mechanisms of electrochemical transduction which explain the sensitivity of fibroblasts to electric fields. Recently they discovered that calcium currents regulate the rate of protein incorporation into fabricated ligaments and the rate of breakdown by digestive enzymes. By blocking calcium currents with specific drugs, the fibroblast acts to breakdown the matrix. This discovery promises to be useful to control excessive scar formation which occurs in burn victims and certain people who are genetically predisposed to excess scarring.

Fabrication of living tissue equivalents in the laboratory is a new concept already proving to be a clinically acceptable concept for skin replacement. Recently, Professor Lee and students have succeeded in demonstrating the feasibility of fabricating ligament-like materials. The tissues are viable and under appropriate conditions will increase in strength by more than 25 fold over a 3 month period. Considerable strengthening is required before these ligaments can be used clinically.

Progress continues to be made towards a complete biophysical understanding of electrical trauma. The kinetics of membrane rupture at supra-physiologic temperatures has been defined. These experimental results were incorporated into a numerical simulation of the arm's and forearm's thermal response to Joule heating to determine the probability of significant heat damage to cells as a function of contact voltage, duration of contact and position in the upper extremity. Professor R.C. Lee organized the symposium Electrical Trauma: Biophysical Mechanisms of Tissue Injury and Clinical Concepts, to be held at the University of Chicago in July, 1989, where he now holds an appointment as Associate Professor of Surgery and Anatomy. His work, as of now at the University of Chicago, will continue to include a collaboration with Professor E.G. Cravalho on the electrical trauma project under the auspices of the Electric Utilities Program.

The work of Professor M.L. Gray and her students continues to be directed towards understanding the mechanisms by which connective tissue growth, development, and remodeling are influenced by mechanical forces. Current work includes an examination of the effect of compressive stress on mandibular condyles grown in vitro. In work more directly focusing on mechanical transduction mechanisms in cartilage, Professor Gray is pursuing a preliminary discovery that compression-induced changes in mobile ion concentrations is linked to the alternations in cell synthesis observed during physiological compression. In collaboration with co-workers at Beth Israel Hospital, Professor Gray continues to develop nondestructive techniques using NMR technology for measuring mobile ion concentrations within connective tissues. Such techniques would enable future investigations of the presumed role of tissue ionic properties in determining tissue function and cell activity.

UTILITY SYSTEM PLANNING AND OPERATION

During the past year this area of the laboratory has been in the process of evolution in reaction to the death in July of 1988 of F.C. Schweppe. Professor M. Ilic, on leave from the University of Illinois, Champaign/Urbana, and Professor I. Perez Arriaga from the Instituto de Investigacion Technologica, Madrid, Spain along with Professor J.L. Kirtley, and Drs. S.D. Umans and R.D. Tabors provided the impetus to complete a number of research projects and continued others. In addition, Professor T.H. Lee provided support through his work with Dr. Tabors in energy systems analysis and planning.

During the Spring semester, Dr. Tabors, with Professors Ilic and Perez, revamped and

presented 6.683 Planning and Operations of Electric Power Systems, which had formerly been taught by Professor Schweppe.

Professor Kirtley and his colleagues have completed RAPID: the RAdial Panel Installation Designer. This is a moderately expert design program for electric power distribution installations in commercial and industrial buildings. It has a data base capability, can simulate "cold pickup" transients, can calculate fault currents and knows the sizing rules of the National Electrical Code.

During the year Spot Pricing of Electricity (Schweppe, Caramanis, Tabors and Bohn) was published by Kluwer Academic Press as were a series of five articles on Spot Pricing and on the pricing of transmission services written jointly by Schweppe, Caramanis and Tabors. Other work on customer response to Spot Prices was completed by Tabors and Daryanian (Ph.D. 1989) and published by IEEE as articles with coauthors Schweppe and Bohn.

For the past four years the laboratory has been actively developing a "Non Intrusive Appliance Load Monitoring" device for collecting detailed electric energy use data from residences by sampling only real reactive power on the two legs of the incoming power line. The residential phase of this effort is nearing completion with the successful demonstration of the concept in experiments in Rochester Gas and Electric and New England Electric Systems service territories.

James R. Melcher

The Laboratory for Information and Decision Systems (LIDS) is an interdepartmental research laboratory of the Massachusetts Institute of Technology. Its staff includes faculty members, full-time research scientists, postdoctoral fellows, graduate research assistants, and support personnel. Undergraduate students participate in the research program of the Laboratory through the Undergraduate Research Opportunities Program (UROP). Every year several research scientists from various parts of the world visit the Laboratory to participate in its research program.

The fundamental research goal of the Laboratory is to advance the field of systems, communication and control. In doing this, it explicitly recognizes the interdependence of these fields and the fundamental role that computers and computation play in this research. The Laboratory is conducting basic theoretical studies in communication and control and is committed to advancing the state of knowledge of technologically important areas.

As an interdepartmental laboratory, LIDS reports to the Dean of the School of Engineering, Professor Gerald L. Wilson. The Co-Directors of the Laboratory are Robert G. Gallager, Professor of Electrical Engineering, and Professor Sanjoy K. Mitter, Professor of Electrical Engineering.

The Center for Intelligent Control Systems (CICS), an inter-university, interdisciplinary research center operated by a consortium of Brown University, Harvard University and MIT, resides administratively within the Laboratory for Information and Decision Systems.

Thirty-one faculty members, four research staff members and approximately 75 graduate students are presently associated with the Laboratory and the Center. Currently, the Laboratory and the Center provide some 50 research assistantships to graduate students. Undergraduate students also participate in research and thesis activities. A number of postdoctoral and visiting appointments are also made.

Financial support is provided by the National Science Foundation, NASA, the University Research Initiative Program, Bell Communications Research, Inc., NYNEX, the Army Research Office, GTE, IBM, Dupont, General Electric, the Office of Naval Research, Data General, the Air Force Office of Scientific Research, and the National Institutes of Health.

RESEARCH INITIATIVES

The Nematode as a Model Complex System

The National Science Foundation has given an "Expedited Award for Novel Research" to Professor Sanjoy Mitter and Dr. Charles Rockland for this project. Briefly, they intend to take the nematode *C. elegans*, (together with the related species *Ascaris*) with its multiple interacting control structures, as a model "complex system." Such systems require the coordinated

interaction and communication of many components, and may involve highly concurrent and distributed computation and control. These systems must generally interact with and adapt to a changeable environment. At the present time, however, there is not even a suitable language to discuss the organization of such systems, let alone a proper theoretical or mathematical framework. To develop such a framework, Professor Mitter and Dr. Rockland intend to incorporate experimental data and theoretical constructs into a coordinated set of concurrent partial models with varying degrees of mutual influence. Professor Mitter and Dr. Rockland believe that their program may lead to fundamental theoretical insights into the organization of complex systems. A working paper has been produced, setting forth a long-term interdisciplinary program of research. A collaboration has been established with Prof. A. Stretton, Dept. of Zoology, U. of Wisconsin, a leading *Ascaris* researcher.

Three Dimensional Structure Determination

Problems of three-dimensional chemical structure determination provide several test-bed problems for three-dimensional random field estimation which are simultaneously of great intrinsic importance. Solution of these problems is crucial to the understanding of natural biological molecules and for the engineering of novel new modified molecules--catalysts for industrial processes, drugs, and so forth. Furthermore, this is currently a field of intense interest in chemistry and biology with many eager collaborators within MIT. Finally, the understanding developed by studying these three-dimensional problems will transfer to other three-dimensional problems such as signal processing for sequences of images and atmospheric/oceanographic/seismic sensing with detailed, and therefore, three-dimensional, models. To address these problems, a research program involving Professors Alan Willsky and Sanjoy Mitter and Dr. Peter Doerschuk has been initiated.

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. An effort to develop such a theory has been initiated 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 throughout the research community and funding agencies, lead us to believe that this will be an extremely fruitful area for some years to come.

Discrete-Event Dynamic Systems

During the past few years there has been considerable interest in the development of control concepts and algorithms for complex processes that are characterized more by the occurrence of discrete events than by differential equations representing the laws of physics. Such processes are typically man-made--flexible manufacturing systems, computer networks, etc.--and are often best described in symbolic, rather than numeric form. Professor Willsky has initiated a research effort aimed at combining concepts from computer science and from control in order to develop a meaningful theory of control for such systems. In particular, the models and formalisms used in such a study come from the field of computer science (automata, synchronous processes, etc.),

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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.

CURRENT RESEARCH

The current research activities of the Laboratory cover a wide range of theoretical and applied areas in systems, communications, and control. These areas include:

Data Communication Networks

Research in Communication Science and Systems ranges from basic information theoretical studies of networks and communication channels to the architectural design of network protocols. The major objective of this work is to develop the scientific base needed to design data communication networks that are efficient, robust, and architecturally clean. Both wide area and local area networks, both high speed and low speed networks, and both point-to-point and broadcast communication channels are of concern. Some of the topics in this area are multiaccess communication processes, routing, congestion control, diverse traffic mixes, the communication complexity and delay of distributed algorithms, failure recovery, and topological design. Professors Dimitri Bertsekas, Robert Gallager, and Pierre Humblet are conducting this research.

Center for Intelligent Control Systems

The Center for Intelligent Control Systems 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 W. Brockett, Harvard University, Associate Director; and Professor Donald E. McClure, Brown University, Associate Director. The research activities of the Center are loosely grouped into six areas: Signal Processing, Image Analysis and Vision; Automatic Control; Mathematical Foundations of Machine Intelligence; Distributed Information and Control Systems; Algorithms and Architectures; and Experimental Program. A number of outstanding graduate students are appointed Graduate Fellows. Speakers in the 1988/89 CICS Colloquium Series included; Morris Hirsch (Berkeley), George N. Reeke, Jr. (Neurosciences Institute and Rockefeller University), J.L. Lions (College de France and Centre National des Etudes Spatiales), R.T. Rockafellar (University of Washington, Seattle), Ingrid Daubechies (AT&T Bell Laboratories) and John Baras, (University of Maryland). Three workshops were organized by CICS faculty: Workshop on Randomness in Computation (chair, Professor Silvio Micali); Machine Learning Workshop (chairs, Professor Ronald Rivest and Leslie Valiant), and the Workshop on Image Analysis and Vision (chair, Professor Donald McClure).

Multivariable and Adaptive Control

Systematic design of multiple-input-multiple-output systems, using a unified time-domain and frequency-domain framework is an extremely active research area in the Laboratory. Various theoretical and applied studies are being carried out by Professors Michael Athans, Munther Dahleh, Sanjoy Mitter, H. Austin Spang III, Gunter Stein and Lena Valavani and their students. Theoretical research deals with issues of robustness, aggregation, and adaptive control. Recent application-oriented studies include the control of helicopters, submarine control systems, engine control system designs, and issues of integrated flight control.

Fiber Optic Communication Networks

The goal of this work is to identify and resolve the new fundamental network design issues that arise when very broadband optical fiber technology is used. It differs from past network research in that the emphasis is upon effective utilization of the enormous excess bandwidth that this technology makes available rather than upon minimizing the bandwidth the network requires. In the bandwidth-rich situations addressed by this work, the usefulness of such traditional bandwidth conserving techniques as switching and packetization becomes questionable. Professors Pierre Humblet, Robert Kennedy, and Robert Kingston are conducting this research which includes theoretical and experimental components.

Command, Control, and Communication Systems

The study of military Command, Control, and Communication (C3) systems defines basic research directions in the areas of distributed communication and decision problems, organizational architectures, and decision aiding for human decision makers in a stressful environment. Professor Michael Athans and Dr. Alexander H. Levis, together with a large group of graduate students, are developing novel theoretical and algorithmic approaches for this rich class of system-theoretic problems.

Recent advances have been made in the following areas: (a) organization structures based on information-theoretic concepts and Petri Nets; (b) mathematical models of distributed decision problems with limited communications; and (c) distributed dynamic resource allocation problems. Estimation, Statistical Signal Processing, and Inverse Problems

A variety of stochastic estimation, analysis and signal processing problems are being studied by Professors Sanjoy Mitter, George Verghese, and Alan Willsky and their students. Theoretical studies are conducted in the areas of estimation algorithms for spatially distributed random processes, nonlinear filtering, relationships among filtering problems in scattering theory, and the analysis of large-scale systems subject to a variety of very rare events. Complementing this theoretical research are more applied projects, including the design of algorithms for detecting and compensating for sensor or actuator failures, and the development of model-based signal processing algorithms. The specific signal processing problems include the diagnosis of arrhythmias in electrocardiograms, the detection of objects or anomalies given tomographic measurements such as those made using X-rays or ultrasound in medical and industrial nondestructive testing applications or in laser radar imaging systems, the analysis and inversion of spatially-distributed geophysical data, image processing and understanding and computational vision.

Deterministic and Stochastic Nonlinear Dynamical Systems

The theory of nonlinear systems, both deterministic and stochastic, has developed rapidly during the last ten years. There is increasing interest in deterministic nonlinear control and various problems of adaptive control which lead to problems of nonlinear control. In the context of stochastic dynamical systems, problems of the qualitative behaviors of such systems under different time-scales are of great interest. Recent work on nonlinear filtering has shown their relationship to infinite-dimensional, bilinear systems, and there is increasing interest in the understanding of qualitative behavior of nonlinear filters for large and small time-intervals. Finally, research is under way on the subject of control of discrete-event systems. Various investigations in this area are being conducted by Professors Michael Athans, Sanjoy Mitter, John Tsitsiklis, George Verghese, Alan Willsky and their students.

Theory and Algorithms for Optimization

This project focuses on analytical and computational methods for solving broad classes of optimization problems arising in engineering and operations research, as well as for applications in communication networks, control theory, power systems, computer-aided manufacturing and other areas. Currently, in addition to traditional subjects in nonlinear and dynamic programming, there is an emphasis on solution of large-scale problems involving network flows as well as in the application of decomposition methods. The thrust is twofold: first, to find ways to handle the typically huge number of constraints; second, to explore the use of distributed and parallel processing to reduce the computation time needed to solve a problem and to economize on information transfer from remote data collection points to a computation center. This gives rise to fundamental issues involving the synchronization of computation and communication that are as of yet only partially resolved. Professors Dimitri Bertsekas and John Tsitsiklis and their students perform this work.

Information Transfer and Retrieval

Research on information transfer and retrieval focuses on investigating issues concerning the way computer-based information systems can be engaged more easily and effectively by potential human users.

Several current projects center on analytical and experimental investigations of expert computerized intermediary systems to assist users in accessing and operating heterogeneous bibliographic database and retrieval systems. Staff members who have supervised these efforts include Mr. Richard S. Marcus and Professor J. Francis Reintjes. An expert intermediary has been designed and partially implemented which should help make searching a quantified science rather than an informal art through such techniques as automatic (1) ranking by estimated relevance of documents in Boolean searches, (2) recall estimation, and (3) search strategy reformulation based on user relevance feedback.

System Reliability and Risk Management

Research on risk assessment and management is carried out in many MIT departments and laboratories. At LIDS there is interest in describing the reliability of complex systems in terms of what is known about the reliability of their components. Professor Alvin Drake has supervised research on the development of models and algorithms for studying the manner in which uncertainties about component reliabilities are reflected in uncertainty about system reliability. The primary area of application has been to low probability, high consequence risks in nuclear reactor safety. Professor Drake is also concerned with probability assessment, particularly the quantification of expert judgment. A current project is a detailed probabilistic analysis of the sequence of tests used to screen donated blood for the presence of AIDS-associated antibodies.

Adaptive Robust Control

Physically plant models are inherently inaccurate and incorporate both parametric and dynamic modelling uncertainty, often involving a large number of parameters. In many circumstances it may be possible to fragment the set of possible plant models into smaller, more manageable "operating points" for which locally robust controllers may be readily designed using standard methods. The entire problem then reduces to one adaptively "gain scheduling" between these robust controllers. This novel and promising approach to adaptive robust control is being developed by Doctor J. Shamma and Professor Kameshwar Poolla.

HIGHLIGHTS

Dr. Levis was the co-editor of the two volume book set, *The Science of Command and Control*. I: *Coping with Uncertainty*; II: *Coping with Complexity*, published by AFCEA International Press.

Professor Sanjoy Mitter was invited to speak at the Summer Program on Signal Processing at the Institute for Mathematics and its Applications, Minneapolis; at the Third International Workshop on the Bellman Continuum, Sophia-Antipolis, France; and at the Imperial College Workshop on Applied Stochastic Analysis, London.

Alan Willsky received the Distinguished Member Award from the IEEE Control Systems Society in recognition of his contributions to the Society in several positions including Program Chairman of the IEEE Conference on Decision and Control, Associate Editor of the IEEE Transactions on Automatic Control, member of the Board of Governors, and Vice-President for Technical Affairs.

Professor Willsky has been leading the collaborative research efforts with the Institut de Recherche en Informatique et en Automatique, which has included exchange visitors and a one-week workshop held in Rennes, France, June 1989. The areas of research covered by this collaboration include multi-scale signal and image analysis and the theory of discrete-event dynamic systems.

The book *Parallel and Distributed Computation: Numerical Methods* by Professors Dimitri Bertsekas and John Tsitsiklis was published by Prentice-Hall.

Professor John Tsitsiklis received MIT's Edgerton Award for exceptional distinction in teaching, research and scholarship.

Visiting Professor Kameshwar Poola was awarded the Presidential Young Investigator Award by the National Science Foundation.

ROBERT G. GALLAGER
SANJOY K. MITTER

Laboratory for Manufacturing and Productivity

The Laboratory for Manufacturing and Productivity (LMP), an interdepartmental laboratory in the School of Engineering, was established in 1977 to develop a scientific foundation for manufacturing. Currently, 20 faculty members, 60 graduate students, and 30 undergraduates conduct manufacturing research jointly with industrial and government partners. The primary research focus is on the engineering fundamentals of manufacturing, with a focus on processes. Rather than developing better methods of coping with complex manufacturing systems, our goal is to reduce their inherent complexity through improved understanding of processes and systems. This approach enables us to blend basic research with very realistic industrial problems.

In addition to our research agenda, the faculty associated with the LMP are attempting to create a manufacturing discipline by continuously refining the curriculum used to educate engineers in the field of manufacturing, and are playing a major role in the Leaders for Manufacturing Program. Curriculum development is extremely important, as there are very few formal mechanisms in the US for educating students in the area of manufacturing. While "on-the-job" training has sufficed in the past, the increasing complexity of today's manufacturing environment requires an advanced understanding of physical processes, as well as interdisciplinary proficiency.

As an interdepartmental laboratory, the LMP reports to the Dean of the School of Engineering, Professor Gerald L. Wilson. David Hardt, Associate Professor of Mechanical Engineering, serves as Director, Dr. Andre Sharon serves as Associate Director, and Ms. Sally Burns serves as Assistant Director of 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 Intelligent Manufacturing Program, the Knowledge Systems Program, and the Microcellular Plastics Program. Further technology transfer is facilitated by the LMP Industrial Collegium, presently comprised of over 35 companies with a common interest in manufacturing. The collegium serves as an information channel between industry and the LMP.

CURRENT RESEARCH

Research activities in the LMP encompass the following areas:

- * Process Innovation
- * Design/Manufacturing Integration
- * Scheduling and Production Planning
- * Tribology
- * Flexible Automation and Robotics

Process Innovation

A large portion of our research is aimed at alternative manufacturing processes that are inherently less complex, and hence more predictable and consistent. Consistency can be further increased through real-time process control. The evolution of the process is continuously monitored and the input parameters are adjusted to eliminate errors caused by unforeseen parameter variations and process disturbances.

Current projects in this area include novel methods of fabricating composites, real-time control of metal forming and welding processes, polymer processing, microcellular plastics, and laser machining.

Tribology

Tribology, or the study of wear, is providing a better understanding of wear mechanisms, which in turn will lead to a more predictable and reliable product. Ongoing projects at the Laboratory are exploring wear mechanisms in various applications, including magnetic recording media, electrical contacts, and piston-cylinder interaction in internal combustion engines.

Flexible Automation and Robotics

Flexible automation facilitates small-batch manufacturing, which will very likely be the standard mode of operation in the future. Industrial robots are central to flexible automation, but current technology severely restricts their use in manufacturing. It is our goal to extend the capabilities of robots through novel hardware, software, and control strategies. Direct-drive robots and macro/micro manipulators are among the robot architectures studied in the Lab.

We are also investigating other issues in flexible automation including planning, reconfigurable fixtures, sensors, reconfigurable die-surfaces for metal forming, and off-line programming.

Design/Manufacturing Integration

This emerging area concerns itself with the integration of the various phases associated with turning a concept into a deliverable product. These phases include design, manufacturing, quality control, marketing, etc. Much research is needed to develop the formal methodologies and tools that will facilitate such integration. Current efforts in the Lab are focused on formalizing the design process, as well as providing tools such as expert systems to aid the designer.

Scheduling and Production Planning

Managing and optimizing product flow through a factory is crucial to manufacturing competitiveness. In the LMP we are conducting research aimed at modelling and "optimally" scheduling the flow of product through manufacturing lines.

NEW APPOINTMENTS

Dr. Andre Sharon was named Associate Director of the LMP. Dr. Sharon received his Ph.D. in Mechanical Engineering from MIT, specializing in controls, electromechanical design, and robotics. He also brings several years of industrial experience to his new post, having worked in both development and manufacturing research in the computer industry. In addition to his own research agenda, Dr. Sharon will work closely with manufacturing companies to identify important manufacturing issues and to evaluate the role that the LMP should play in addressing those issues.

NEW INITIATIVES

A new industry consortium entitled "Processing of Microcellular Plastics and the Role of Dissolved Gas in Polymers" has been formed by Professor Nam P. Suh, Professor of Mechanical Engineering. Microcellular plastics are created by dissolving gas in the plastic, generating millions of tiny voids ("microvoids"). This can reduce the amount of material in the plastic by 20 - 80 percent, translating into a cost-reduction of 10 - 40 percent, with an increase in toughness as well. It is the goal of this consortium to advance the microcellular technology with an eye on the requirements for mass production, and to do basic research on the effects of dissolved gases on the processing and use of polymers.

DAVID E. HARDT

Leaders for Manufacturing Program

The Leaders for Manufacturing program is a five-year experimental educational/research partnership between 11 major US manufacturing firms and MIT's Schools of Engineering and Management. Its overall goals are to discover and codify guiding principles for manufacturing, and educate future leaders for manufacturing firms. The program adopts a broad definition of manufacturing, including product and process development through production, sales, and service, and emphasizes the importance of integration.

The essence of the Leaders program can be summarized in three words: people, principles, and partners. The people include company leaders and practitioners, faculty, and students. The principles are those now guiding the current best practice and those that emerge as new paradigms for future manufacturing. The partnership is tripartite, consisting of industry and MIT's Schools of Engineering and Management.

EDUCATION

The key educational component of the program is a competitive two-year graduate experience integrating management and engineering, including a six-month internship at a sponsor company. Students participating in this segment of the program receive fellowships to gain valuable experience working on major issues of interest to both MIT and the participating companies while earning two highly regarded master's degrees in management and engineering. The two degrees provide the fellowship program's graduates with unique qualifications for serving as agents of change. The Leaders program also benefits students in other educational programs at MIT by enhancing their traditional master's or doctoral degrees with the broader perspective that manufacturing research brings to graduate study.

The program's research component is a multidimensional effort linking university research capabilities to relevant problems that are grounded in industrial needs. This effort is vastly aided by the partner companies' substantial human and capital resources.

PEOPLE

The program seeks to attract some of the nation's most capable, farseeing young people to a challenging, multidisciplinary field. To strengthen their learning experience, participating corporations are opening their factories to become research laboratories and living classrooms for interdisciplinary teams of faculty and students, and the program is offering access to some of the world's most innovative minds. Students thus gain solid educational and practical experiences to further their careers in manufacturing.

Launched in the spring of 1988, the Leaders program draws on more than five years of research and discussion among industry leaders and MIT faculty. The program responds to an increasing number of questions posed by American manufacturers about how to improve productivity and compete globally. It begins to address issues for improving American industrial performance that were raised by the MIT Commission on Industrial Productivity during the Commission's two-year study of eight American manufacturing industries in a global market. The Commission identified six patterns of behavior underlying America's productivity problems: outdated strategies, short time horizons, technological weaknesses in development and production, neglect of human resources, failures of cooperation, and conflicting government and industry purposes. These patterns, along with the Commission's findings on the eight industries and its recommendations, are described in the book *Made in America*, published by the MIT Press in 1989.

With the depth and breadth of its commitments, the Leaders program is perhaps the largest cooperative venture ever undertaken by a major engineering school, a major management school, and industry. Five departments in MIT's School of Engineering - Aeronautics and Astronautics, Chemical Engineering, Electrical Engineering and Computer Science, Materials Science and Engineering, and Mechanical Engineering - are cooperating with the School of Management and 11 firms. One hundred industrial practitioners are currently working in the program with more than 50 each of the MIT faculty, Fellows, and graduate research assistants.

354 School of Engineering

The program is attracting some of the world's best and brightest to discover and incorporate principles governing world-class manufacturing into a curriculum that will prepare outstanding young people for leadership in American manufacturing firms. To do so, the program seeks to restructure academic and industrial environments, refurbish manufacturing's tarnished image, and forge new relationships within and between universities and industry, management and engineering.

RESEARCH

The Leaders program funds three types of research: Fellows' projects at partner companies, unrestricted junior faculty research, and long-term basic research in manufacturing. Together, these research opportunities involve approximately 50 Institute faculty members.

The Fellows' projects, each conducted during 6 months of work at an industrial site, are designed to offer the program participants a broad exposure to manufacturing needs. Student teams, supervised by faculty and industry associates, address issues that have been identified through collaboration between the Leaders faculty and the partner firms to be of special concern to both the sponsoring companies and the broader manufacturing community. The partner companies' different markets, technologies, and cultures afford ideal test beds for program participants to learn the underlying principles of future manufacturing.

Fellows' projects are generally selected to explore at least one of a few major themes recommended by participating industry representatives and faculty. In support of the 1989 themes, "design for manufacturability" and "time to break even", students are addressing a variety of topics in their thesis research, including new materials, product development, process control and improvement, computer-integrated manufacturing, design-for-manufacturing computer tools, supplier relations, and manufacturing resource allocation strategies.

The short-term Fellows' research projects serve as a backdrop for longer-term intellectual efforts in manufacturing. Most of this basic research is conducted at MIT, preferably through collaboration among Leaders program faculty participants that cuts across traditional disciplinary boundaries. Currently, the program is funding 28 projects. The faculty have elected to favor projects that distinctly differ in content and style from traditional academic research practice, and that encourage students and faculty to work together in teams.

The Leaders program also offers grants for unrestricted research to its junior faculty. Through these grants, the program currently supports approximately 20 research assistants investigating a broad range of topics. One such project investigates the cost and manufacturability of hybrid power supplies; its results will be used to develop an undergraduate course on issues in manufacturing electronic systems.

H. Kent Bowen, Co-Director
Thomas L. Magnanti, Co-Director
Judith V. Stitt, Communications Director

Materials Processing Center

The Materials Processing Center (MPC), formed within the Massachusetts Institute of Technology's (MIT) School of Engineering in 1980, catalyzes the generation and transfer of scientific information and technology necessary to promote progress in the materials processing field. Founded with a NASA grant to establish a research base in materials processing, the MPC has rapidly expanded to a current annual research budget of \$7.1 million. NASA still provides about 15 percent of the MPC's total budget, with 27 percent provided directly by industry, and another 58 percent from government agencies.

As an interdepartment center, the MPC reports to the Dean of the School of Engineering, Professor Gerald L. Wilson. The Director of the center is Ronald M. Latanision, Professor of Materials Science. The Associate Director is Dr. George B. Kenney.

INTERDISCIPLINARY, FUNDAMENTAL RESEARCH

The MPC's basic philosophy is that it is through processing that the internal structure on both the macroscopic and the microscopic level can be controlled, thus influencing a material's properties and performance. Processing for control of structure must be based on scientific fundamentals, rather than the more traditional empiricism.

MPC research covers a broad range of materials and activities, with a number of common themes. The foremost theme running through all MPC research is the control of structure, properties, and performance at costs that are acceptable both socially and economically. Projects have both practical and fundamental significance, with many related to low-gravity processing in space. Researchers in both ground-based and microgravity-based studies are increasing their use of mathematical modeling techniques as a research tool. They are also exploring ways to achieve on-line control of materials processing.

Another theme common to MPC projects is the interdisciplinary nature of the research. Projects typically involve a number of faculty, staff, and students from several departments, including Chemical Engineering, Civil Engineering, Physics, Nuclear Engineering, Materials Science and Engineering, Mechanical Engineering, Electrical Engineering and Computer Science, and Chemistry.

A more detailed description of research activities can be found in the *Materials Processing Center Report 1987-1988*. This volume is available from the MPC headquarters in Building 12-007.

EDUCATION: BEYOND THE TRADITIONAL

An MPC goal is to increase the number of materials processing students and professionals, thereby expanding the talent base available for industry. This expansion is crucial, since requests from industry for materials research and development engineers and scientists are about three times the number of these professionals graduating.

High School Outreach Program

Over the past year, the MPC refined an innovative program to expose high school students to the rewards of basic scientific research and engineering here at MIT. In two separate tours, outstanding science students from Massachusetts high schools and from the Massachusetts Pre-Engineering Program (for black and hispanic high school students) were invited to tour a number of MIT's materials processing research labs. The tours introduced the students not only to materials processing research, but to the impact of science and technology on society and politics as well. By reaching out to students at a time in their lives when they are formulating their goals for the future, the MPC hopes to encourage them to pursue a science or engineering career.

Science and Engineering Program for High School Teachers

An exciting new program, the MIT Science and Engineering Program for High School Teachers, has grown out of the high school tour program. While student visits to MIT serve an important purpose, the MPC believes that it is the science teachers themselves who are the key to catalyzing student interest and enthusiasm. This past June, the MPC selected 51 high school teachers from the New England states to attend an intensive one-week science and engineering program designed to explore with them how engineers apply basic scientific principles to meet the technological challenges and needs of commerce and society. The teachers were overwhelmingly responsive to our initial effort; the group plans to meet again in November to develop the recommendations and actions necessary to reverse the existing decline in science literacy and engineering enrollment in the United States and to put in place a lasting solution. The MPC considers the grass roots phenomenon initiated by this committed group of secondary school science educators to be an important first step.

Fellowships and Summer Scholarships

The MPC, through the Collegium, sponsors graduate student fellowships and undergraduate summer scholarships. The summer scholarship program, established in 1982, seeks to alert undergraduate students from a variety of disciplines to the opportunities available in a career in materials processing at MIT. For the summer of 1988, the MPC awarded four summer scholarships to sophomores and juniors enrolled in physics, mechanical engineering, electrical engineering, and materials science in universities throughout the United States. During the summer, these undergraduates participate in ongoing materials processing research programs before returning to their respective schools in the fall to complete their undergraduate programs. Similarly, the fellowship program, also begun in 1982, endeavors to attract the very best entering graduate students to materials processing. For the 88/89 academic year, the MPC offered seven fellowships to students in the Departments of Materials Science and Engineering, Chemical Engineering, Electrical Engineering and Computer Science, and Mechanical Engineering.

The undergraduate summer scholarship and the graduate student fellowship programs are now linked by a three-year, full fellowship that is offered to the very best of our undergraduate summer scholars. The first such fellowship was awarded to Chrysanthe Demetry, who began her graduate studies last fall with Professor Yet-Ming Chiang.

COLLABORATION WITH INDUSTRY

The MPC believes that due to the rapid rate of scientific and technological innovation, new mechanisms must be developed to facilitate the transfer of scientific information and technology to industry in ways that go beyond the traditional modes of research publication and student graduation. Collaboration with industry is critically important to the university, providing academic programs with the long-term direction necessary to maintain a high degree of relevance to rapidly evolving research needs.

Since its inception, the MPC has encouraged a close relationship with industry through its industrial advisory board, industry collegium, and multi-client research consortia. The board, whose 25 members all come from U.S. industry and government, annually reviews ongoing MPC research programs and policies. The collegium, now with 66 corporate member companies worldwide, encourages close contact between industrial representatives and MPC personnel through seminars, visits, and tours of the research facilities. Person-to-person contact between visiting scientists from these companies and MPC faculty, staff, and students encourages the flow of creative ideas in both directions, while providing excellent opportunities for bilateral information and technology exchange.

The MPC adopted the consortia, or multi-client sponsored research concept, in 1980 to promote collaborative, generic materials processing research. A new consortium now being formed will focus on the packaging of electronic, magnetic, and optical devices. This program will combine the talents of experts in microsystems technology, polymer synthesis, and materials science to understand in greater detail the materials and processing issues that are crucial to device reliability and cost optimization. It will join six previously organized consortia: the Ceramics Processing Research Laboratory, the Laboratory for Inorganic Composites, the Materials Synthesis Laboratory, the Materials Systems Laboratory, the Mathematical Modeling Laboratory, and the Resistance Welding of Automotive Steels. Through groups such as these, the MPC strengthens the link between basic research at the university and innovation in industry.

TIMELY INFORMATION EXCHANGE

Each year, the MPC hosts several symposia, each covering an area of ongoing research in materials processing at MIT, for the benefit of the Collegium member companies. The major rewards of the seminars, which have been well attended by industrial, university, and government personnel, are the timely dissemination of research results and the ensuing exchanges between speakers, MPC staff, and attending industrial representatives. These symposia also provide an opportunity for graduate students to become acquainted with practicing engineers and scientists from industry. Symposia held last year dealt with "Novel Processing Technologies for Electronic Materials" (in cooperation with Osaka University, Japan, and the Industrial Liaison Program) and "Investment Opportunities in Materials Markets."

This past March the MPC invited Dr. Paul C. Maxwell, Science Consultant to the Committee on Science and Technology in the House of Representatives, to present the viewpoint of Congressional policymakers regarding high critical temperature superconductor (HT_cSC) research in America. The special guest seminar, entitled "Federal Policies Regarding Higher Temperature Superconductors," was sponsored jointly by the MPC and the Center for

Technology, Policy, and Industrial Development. Although Congress still faces problems in its efforts to create a national materials policy, Dr. Maxwell found reason to be optimistic. The unique publicity generated by HT_cSC news releases placed, for the first time, a material in the public's limelight. This has encouraged Congress to think in terms of a national plan for HT_cSC research that could serve as a model for materials in general.

The MPC, through its direct interaction with industrial personnel, promotes the technology transfer upon which innovation in materials processing is based. For the past nine years, the MPC has provided a focus and forum in which academic, industrial, and government personnel can broaden their knowledge while collaboratively developing new scientific and technological skills in materials processing. Through such collaboration and cooperation, we expect to exercise our leadership role in the evolution of new materials, the development of the processing technologies required to manufacture with these materials, and, ultimately, to transfer materials processing know-how into the worldwide marketplace.

R.M. LATANISION

SCHOOL OF HUMANITIES AND SOCIAL SCIENCE

SCHOOL OF HUMANITIES AND SOCIAL SCIENCE

Introduction

This year the School of Humanities and Social Science continued its concerns with curricular development and initiatives as evidenced by the formal introduction of the new Humanities, Arts and Social Science Distribution (HASS-D) System and a new HASS minor. Affirmative action continued to be the focus of substantial effort. The faculty within the School received a number of honors and awards; fund-raising activities continued at a high level; and a number of administrative changes took place.

Undergraduate Education

Under the new HASS-D System students must take three distribution subjects from five categories: Literary Studies; Language, Thought, & Value; The Arts; Historical Studies; Cultures & Societies. In addition, students must take at least one subject from the two categories that are focussed on humanistic areas (Literary Studies; Language, Thought, & Value) and at least one subject from the categories that focus on the Social Sciences (Historical Studies; Cultures & Societies). The new distribution system began in the fall of 1988 and was required for all entering freshmen, while the current HUM-D System will continue to be available to existing upperclassmen. In an effort to rejuvenate the Distribution System, faculty have been encouraged to develop new HASS-D subjects. For the academic year 1988-89 there were 17 new subjects in the HASS-D System, with a total of 57 subjects. For the academic year 1989-90 there will be some additional 12 new subjects, and a total of 64 subjects.

In an effort to provide an intermediate option between the required concentration of three subjects within the HASS fields and the HASS major (which typically requires approximately 15 subjects in a given field), a HASS minor was instituted, beginning in the academic year 1988-89, which consists of six subjects in an approved HASS field, one of which must be an Institute-wide elective. Minors in fifteen fields are currently approved, and the minor has proved to be an attractive option to undergraduates.

In addition, this year the faculty voted to change the designation of the degree in Humanities from the general formulation of Course XXI: Humanities to the specific formulation of the fields within the Humanities (e.g. Course XXI: History). This is consistent with the increasing intellectual and scholarly strength of the fields within the Humanities and recognizes their growing importance in the MIT curriculum.

Affirmative Action

Although the affirmative action record of the School of Humanities and Social Science appears to be strong relative to that of the Institute, it is important to realize that the representation of women within the fields of humanities and social science is relatively large. Consequently, although the School's record is impressive relative to the Institute, its record relative

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to the pool is about average. Within the School, there are 31 women faculty, which represent 21 percent of the total. Of these 21 are tenured (19 percent of the tenured faculty) and 10 are untenured (27 percent of the untenured faculty). Over the past four years, the total number of women faculty has remained essentially constant, although the total number of tenured women has risen somewhat, while the number of untenured women has fallen.

Although the record within SHSS is relatively strong with respect to women, it is less so with respect to minority faculty. There are currently three tenured minority faculty and one untenured minority faculty within the School. The School of Humanities and Social Science is committed to increasing the number of minority faculty members. To this end, the Departments, Sections, and Programs within the School have been told that no search plan may go forward without the determination of the relevant pool of minority appointments. Moreover, each unit meets regularly with the SHSS Equal Opportunity Committee to discuss a strategy for developing target of opportunity appointments. Although the yield from these activities has been rather discouraging in the past, we are hopeful that it will be more productive in the future.

Honors and Awards

The faculty within SHSS have been active this year and received a number of honors and awards. The most notable among them were the following: Professor Lucian W. Pye of the Political Science Department and Professor Merritt Roe Smith of the Program in Science, Technology, & Society respectively served as President of the American Political Science Association and The Society of the History of Technology, while Professor Peter A. Diamond of the Economics Department was elected Vice President of the Econometric Society. Professors Kenneth L. Hale and Judith J. Thomson of the Department of Linguistics and Philosophy were elected to the American Academy of Arts & Sciences. Honorary degrees were awarded to professor Rudiger W. Dornbusch (Department of Economics) by the University of Basle; to Institute professor Morris A. Halle (Department of Linguistics & Philosophy) by Brandeis University; and to Professor Thomas S. Kuhn (Department of Linguistics & Philosophy) by Ohio Wesleyan University. Associate Professor Harriet N. Ritvo of the Writing Program received a Guggenheim Award and a fellowship from the National Endowment of the Humanities. Professor Catherine V. Chvany of the Foreign Languages & Literatures Section received a medal for outstanding scholarly contributions at the Fourth international Congress of Slavists and Professor Claire J. Kramsch of the Foreign Languages & Literatures Section received the National Nelson Brooks award for the teaching of language and culture from the American Council on Teaching of Foreign Languages. Assistant Professor Charles Stewart III of the Political Science Department received MIT's Everett Moore Baker Memorial Award for Excellence in Undergraduate Teaching and The Women's Studies Program received MIT's Sizer Award for the most significant improvement to MIT education.

Fund-Raising and The Campaign

Fundraising activities for the School of Humanities and Social Science continue to move forward. After considerable success with major foundations, efforts this year were directed toward the identification of MIT alumni with an interest in SHSS. Those efforts resulted in a number of cultivational

events which are expected to bear fruit in the near future. Three major gifts were received during the last year. Harry Kalker, 23 CE, provided funds for the creation of a program to bring select State Department personnel to MIT for a summer course of study at the Center for International Studies. A major gift was received from James Levitan, 45 CH, for the establishment of a Faculty Development Fund for the Humanities faculty. Professor Pentti Kouri, EC 75, funded a Career Development Chair in his name within the Economics Department. In addition, the Knight Science Journalism Program received a major challenge grant from the Knight Foundation, which should lead to the permanent endowment of that program. David Lundberg became Director of Resource Development for the School of Humanities and Social Science last fall, and he has proved to be an energetic and effective advocate for the School.

Administrative Changes

This year has seen a number of administrative changes within the School, with the following individuals resigning as Section or Department Head: Professor Richard L. Cartwright from Linguistics and Philosophy; Professor David M. Epstein from Music and Theater Arts; Professor James Howe from Anthropology/Archaeology; and Professor Richard M. Douglas from History. Replacing them in their respective faculties will be Professor Wayne O'Neil of Linguistics and Philosophy; Professor Jeanne S. Bamberger of Music and Theater Arts; Professor Jean E. Jackson of Anthropology/Archaeology; and Professor Bruce Mazlish of History. In addition, Professor Donald L. M. Blackmer resigned as Head of Political Science last January and was replaced by Professor Suzanne D. Berger.

We will miss the insights and administrative wisdom of the departing Section and Department Heads, but wish them well as they return to a professional life focussed on scholarship and teaching. We are also grateful to the new Department and Section Heads and appreciate their willingness to undertake substantial administrative duties.

TABLE I

Enrollment in Humanities, Arts, and Social Science Subjects:
1988-89

Field	Elective Subjects		Hum-Distribution		HASS-Distribution		Totals	
	# of Subjects	# of Students	# of Subjects	# of Students	# of Subjects	# of Students	# of Subjects	# of Students
Anthropology/ Archaeology	10	83	1	13	4	86	15	182
Economics	17 ³⁸	1329	1	34	1	15	19 ⁴⁰	1378
Foreign Lang & Literature	62 ⁹⁹	1209	3 ⁴	78	10 ¹⁶	210	75 ¹¹⁹	1497
History	24	350	13 ¹⁴	304	5	204	42 ⁴³	858
History of Art & Arch	3	15	3	91	1	37	7	143
Interdis	3	57	0	0	0	0	3	57
Linguistics	1	17	1	27	0	0	2	44
Literature	23 ²⁴	384	1	13	24 ³³	853	48 ⁵⁸	1250
Music	16 ²²	460	1	10	10 ²³	408	27 ⁴⁶	878
Philosophy	20	391	1	32	8	359	29	782
Political Science	23	416	1	32	6	244	30	692
Psychology	8	454	0	0	1	388	9	842
STS	6	51	3	105	3	86	12	242
Theater Arts	6	37	0	0	0	0	6	37
Urban Studies	6	109	3	70	1	51	10	230
Visual Arts	6	85	1	26	0	0	7	111
Writing	30 ⁴⁰	568	6 ¹³	189	2 ⁴	99	38 ⁵⁷	856
TOTALS	263 ³³⁸	6015	39 ⁴⁸	1024	76 ¹⁰⁶	3040	378 ⁴⁹²	10079

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 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 1989

Fields of Concentration	Class of 1992	Class of 1991	Class of 1990	Class of 1989	Totals in Fields
American Studies	(0) 0	(1) 0	(0) 0	(5) 5	(6) 5
Ancient & Medieval	(0) 0	(1) 0	(3) 0	(4) 3	(8) 3
Anthropology/Archaeology	(0) 0	(2) 0	(9) 0	(7) 7	(18) 7
Economics	(1) 0	(27) 4	(83) 27	(217) 198	(328) 229
Film & Media Studies	(0) 0	(0) 0	(5) 1	(10) 7	(15) 8
Foreign Languages **	(2) 0	(44) 10	(88) 39	(165) 149	(299) 198
History	(0) 0	(4) 2	(42) 17	(81) 74	(127) 93
History of Art	(0) 0	(1) 0	(3) 0	(8) 8	(12) 8
Labor in Industrial Society	(0) 0	(0) 0	(0) 0	(1) 0	(1) 0
Latin American Studies	(0) 0	(0) 0	(0) 0	(1) 1	(1) 1
Linguistics	(0) 0	(0) 0	(5) 0	(12) 11	(17) 11
Literature	(0) 0	(15) 4	(28) 12	(111) 94	(154) 110
Music	(3) 0	(21) 2	(55) 14	(104) 93	(183) 109
Philosophy	(0) 0	(3) 0	(11) 0	(81) 64	(95) 64
Political Science	(3) 0	(11) 0	(29) 9	(69) 63	(112) 72
Psychology	(0) 0	(10) 3	(46) 14	(124) 112	(180) 129
Russian Studies	(0) 0	(0) 0	(3) 0	(5) 4	(8) 4
Science, Technology, & Society	(0) 0	(0) 0	(5) 1	(22) 18	(27) 19
Theater Arts	(0) 0	(1) 0	(1) 1	(8) 6	(10) 7
Traditions & Texts	(0) 0	(0) 0	(0) 0	(4) 2	(4) 2
Urban Studies	(0) 0	(3) 1	(2) 0	(5) 4	(10) 5
Visual Arts & Design	(0) 0	(3) 0	(11) 2	(27) 24	(41) 26
Women's Studies	(0) 0	(4) 0	(4) 1	(10) 10	(18) 11
Writing	(0) 0	(13) 0	(32) 11	(57) 49	(102) 60
Special Concentrations	(0) 0	(6) 3	(19) 12	(33) 31	(58) 46
TOTALS	(9) 0	(170) 29	(484) 161	(1171) 1037	(1834) 1227

* The parenthetical figure is the number of proposed concentrations in the given class and fields; the figure to its right is the number of these concentrations that have been completed.

** Figures for subfields of Foreign Languages and Literatures:

French	(0) 0	(17) 4	(24) 9	(55) 51	(96) 64
German	(0) 0	(9) 2	(21) 12	(31) 29	(61) 43
Japanese	(0) 0	(4) 1	(10) 3	(19) 16	(33) 20
Russian	(1) 0	(5) 0	(6) 6	(14) 13	(26) 19
Spanish	(0) 0	(6) 1	(17) 6	(34) 29	(57) 36
World Literature	(0) 0	(0) 0	(6) 1	(6) 6	(12) 7
Other Languages	(1) 0	(3) 2	(4) 2	(6) 5	(14) 9

TABLE III**Undergraduate Majors in the School of Humanities and Social Science***

<u>Year</u>	<u>Economics</u>	<u>Humanities**</u>	<u>Philosophy</u>	<u>Political Science</u>	<u>Total</u>
1975-76	67	41	3	24	135
1976-77	67	31	7	25	130
1977-78	52	34	7	21	114
1978-79	48	38	5	30	121
1979-80	44	37	9	36	126
1980-81	50	40	11	30	131
1981-82	51	49	9	32	141
1982-83	48	37	7	28	120
1983-84	48	24	3	22	97
1984-85	52	30	2	15	99
1985-86	51	52	5	26	134
1986-87	49	57	7	21	134
1987-88	76	77	9	40	202
1988-89	103	52	11	43	209

* As registered in the second term of academic year 1975-76 to 1988-89. Data taken from the Registrar's fifth-week report.

** These figures do not include double majors who registered first in a course other than Humanities. (If you include double majors, the figure is 85.)

TABLE IV**Graduate Students in the School of Humanities and Social Science***

<u>Year</u>	<u>Economics</u>	<u>Linguistics & Philosophy</u>	<u>Political Science</u>	<u>Total</u>
1975-76	120	49	89	258
1976-77	114	46	91	251
1977-78	123	45	102	270
1978-79	121	48	96	265
1979-80	138	63	143	344
1980-81	126	66	121	313
1981-82	111	55	142	308
1982-83	136	51	163	350
1983-84	113	52	99	264
1984-85	108	53	121	282
1985-86	130	59	171	360
1986-87	105	55	115	275
1987-88	120	72	157	349
1988-89	127	67	118	312

* As registered in the second term of academic year 1975-76 to 1988-89 (including special graduate students). Data taken from the Registrar's fifth-week report.

TABLE V

HASS MINOR APPLICATIONS
FOR CLASSES OF 1989, 1990, AND 1991

FIELD	TOTAL APPLICATIONS
Anthropology/Archaeology	1
Economics	37
French	10
German	5
History	10
Literature	22
Music	38
Philosophy	3
Political Science	16
Psychology	18
Russian	1
Science, Technology, and Society	1
Spanish	5
Women's Studies	6
Writing	16
TOTAL	189

Humanities, Arts, and Social Sciences Office

HUMANITIES, ARTS, AND SOCIAL SCIENCES INFORMATION AND SERVICES CENTER

The HASS Office had a productive year serving the MIT community with Ruth Spear continuing to serve as its coordinator. There was an increase in inquiries from both faculty and students regarding the new HASS-Distribution system and the new HASS minor programs. The office continued to serve the community regarding Harvard Cross-Registration, HASS Transfer Credit, HASS Concentrations and general Institute information.

HASS Enrollment Statistics by Field and Subject -- Recent Trends

The total number of students taking HASS subjects in 1988-89 increased slightly (299) from the previous year (9780 to 10,079). This total, however, remains lower than it was in 1984-85 (10,373). Enrollments in elective subjects increased this year (6015) by 673 from last year and is now closer to the 1984-85 figure of 5736. Enrollments in Distribution subjects show a decline from last year of 338 students (from 4402 to 4064); this is also lower than the 1984-85 figure of 4637. Hum-Distribution enrollments were 1024 and HASS-Distribution enrollments were 3040 in 1988-89. The number of HASS subjects and autonomous sections (sections that meet independently rather than in lecture once or twice a week and then divide into discussion sections) offered did not change much from 1987-88. It is important to note that the number of Distribution subjects and autonomous Distribution sections offered decreased by 15 and 30 respectively from 1987-88. This is probably due to the implementation of the HASS-Distribution system. The most noteworthy changes within individual fields are: an increase in Economics enrollments after a two year decline (1378); an increase in Literature enrollments after a one year drop (1250); and a significant decrease in Visual Arts and Design enrollments (335 in 1987-88 to 111 in 1988-89) which also has had a general decline over the past three years (from 572 to 111).

HASS Concentrations: Patterns of Popularity

Economics is again the most popular field of Concentration this year followed by Foreign Languages and Literatures, Music, and Psychology, respectively. This has been the order of popularity since 1987. There are 328 proposed concentrators in Economics, 299 in Foreign Languages and Literatures, 183 in Music, and 180 in Psychology.

HASS Minor Programs

1988-89 was the first year of the HASS minor programs which included 15 different fields. There were a total of 189 students who applied for a minor program: 59 in the class of 1991, 74 in the class of 1990, and 56 graduating in 1989. There are students in all 15 minor fields. The most popular minor programs are: Music (38), Economics (37), Literature (22), and Psychology (18).

Harvard Cross-Registration

Applications for Cross-Registration at Harvard remained stable at 182 students taking 183 subjects. There were no significant changes in field choices from last year. Languages not offered at MIT are the most popular subjects taken at Harvard, specifically Chinese, Italian, and Korean.

COURSE XXI

The MIT Faculty approved a change in the designation of the majors for the sections and programs within Course XXI from the generic designation "Humanities" to the following designations: Anthropology/Archaeology, Foreign Languages and Literatures, History, Literature, Music, Science, Technology, and Society, and Writing. Effective AY '90, the Bachelor of Science Degree in Course XXI will be designated by these specific fields. The primary reasons for this change are two: 1) to ensure that there is uniformity not only within the majors designated through Course XXI, but also with respect to the other majors offered in the School of Humanities and Social Science and in the other Schools; and 2) to recognize the increasing importance of the Humanities within a MIT education.

Course XXI Students

The May 1989 combined enrollment in XXI, XXI-E, XXI-S was 85 (33 of whom were double majors). The distribution of these students into the ten available humanistic fields remained steady, with Literature still dominant, followed closely by Music and Writing.

Course XXI Degrees

Three students received their S.B. in February 1988 (one in XXI, one in XXI-E, and one in XXI-S); 28 students received the S.B. in June 1988 (17 in XXI, six in XXI-E, and five in XXI-S) -- for a total of 31 for the academic year.

Course XXI Honors and Awards

Among the more notable distinctions and honors achieved by Course XXI students this year were:

Phi Beta Kappa: Jackson A. Bross '89, John Buck '89, Kenneth Goodson '89

Burchard Scholars: Elisabeth Stock '90

Louis Sudler Prize in the Arts: Kenneth Goodson '89

William Eugene Edgerton Award: Jackson A. Bross '89

I. Austin Kelly III Competition: Corinne Wayshak '89

Writing Prizes: Susan Landsman '90, Peter Mead '89, Stephanie Saulter '89, Carol Waldman '89, Warren William '89

PHILIP S. KHOURY

Department of Economics

INTRODUCTION

The Economics Department's scientific activity continued at an intense pace, along with involvement by the faculty with national and international policy issues. Revisions were made in undergraduate and graduate macroeconomics courses and graduate theory courses. Two new junior faculty appointments were made, and the Department was unusually successful in recruiting new graduate students for the fall term of 1989.

FACULTY PERSONNEL

Thomas Lemieux, who specializes in labor economics and is obtaining his Ph.D. from Princeton University, was appointed as Assistant Professor. The appointment as Assistant Professor of John Heaton, who specializes in macroeconomics and finance and is obtaining the Ph.D. from the University of Chicago was made, jointly, with the School of Management.

Professors Oliver Hart and Jean Tirole were on leave for the year at the Harvard University School of Business and Economics Department, respectively. Professor Stanley Fischer continued on leave as Vice President for Development Economics and Chief Economist at the World Bank.

The visiting faculty included Professor Rebecca Blank of Princeton University, with NSF sponsorship, Professor Mathias Dewatripont of the University of Brussels, Professor Patrick Rey of the Institut National de la Statistique et des Etudes Economiques, and Professor Michael Woodford of the School of Business at the University of Chicago.

STUDENT RECRUITMENT AND ENROLLMENT

To match the recruiting by several other leading economics departments, the highest ranked applicants for admission to the graduate program were invited to visit the Department. The effort was extremely successful and about two-thirds of the 26 winners of National Science Fellowships, who will initiate their graduate studies in economics in the fall of 1989, have accepted the Department's offers of admission. The Department was correspondingly successful in recruiting other students and particularly successful in recruiting women students. As a result, about 40 percent of the class entering in the fall will be women. The entering class will be slightly larger than usual, in part because the number of NSF fellowships awarded almost doubled. The number of graduate students grew slightly this year and enrollments in undergraduate courses also increased.

FACULTY RESEARCH

The research activities of the faculty continue to be quite productive. Following are examples: "Using Privileged Information to Manipulate Markets: Insiders, Gurus and Credibility," (Assistant Professor Roland Benabou with Guy Laroque); "A Model of Growth Through Creative Destruction," (Assistant Professor Philippe Aghion with Peter Howitt);

"Consumption: Beyond Certainty Equivalence," (Professor Olivier Blanchard with Lawrence Summers); "Rational Expectations Business Cycles in Search Equilibrium," (Professors Peter Diamond and Drew Fudenberg); "The World Debt Problem," (Professor Rudiger Dornbusch); "Economic Dualism," (Professor Richard Eckaus); "Games Economists Play: A Non-cooperative View," (Professor Franklin Fisher); "Trends in Worker Demand for Union Representation," (Professor Henry Farber); "Contract Renegotiation and Coasian Dynamics," (Professors Hart and Tirole); "Future Competition in Telecommunications," (Professor Jerry Hausman); Exchange Rate Instability, (Professor Paul Krugman); "Lifetime Incidence and Distributional Burden of Excise Taxes," (Professor James Poterba); "Irreversible Risk As Intertemporal Opportunities," (Professor Jerome Rothenberg); "Macro Constraints on India's Economic Growth," (Professor Lance Taylor); "Product Quality and Vertical Integration in the Early Cotton Textile Industry," (Professor Peter Temin); "Hypothesis Testing with Restricted Spectral Density Matrices," (Assistant Professor Danny Quah with T. Ito); "A Theory of Wage Dispersion and Job Market Segmentation," (Professor Martin Weitzman); "Vacancy, Search and Prices in a Housing Market Matching Model," (Associate Professor William Wheaton).

FACULTY HONORS

Professor Diamond was named to the John and Jennie S. MacDonald Professorship and Professor Paul Joskow was named to the Mitsui Professorship in Problems of Contemporary Technology.

The Department's faculty continue to receive recognition, including invited lectures, awards, prizes, and honorary degrees. The following again represents only a sample. Professor Blanchard lectured in Spain and Sweden, as well as at many U.S. universities. Professor Diamond was elected as a vice-president of the Econometric Society. Professor Dornbusch was awarded the Doctor honoris causa at the University of Basle and gave the invited Clark Lecture at the University of Illinois. Professor Hausman gave the invited Jacob Marschak Lecture for the Econometric Society. Professors Farber, Joskow and Poterba were elected as Fellows of the Econometric Society and Professor Krugman was elected as a member of The Group of Thirty. Professor Taylor gave the V.K. Ramaswami Lecture at the Delhi School of Economics and Professor Temin gave the Robbins Lectures at the London School of Economics & Political Science.

RESEARCH GRANTS AND NEW PROGRAMS

The Sloan Foundation awarded a grant to support the visit of Professor Howard Rosenthal of Carnegie-Mellon University for the next academic year. Professor Rosenthal is a leading political scientist specializing in the use of rational choice theory to explain U.S. political processes. Professor Rosenthal will teach a subject in each term, jointly with Professors Joskow and Tirole. The Rockefeller Foundation supported a conference on international debt relief organized by Professor Dornbusch. The Sloan Foundation also awarded a two year Sloan Research Fellowship to Professor Poterba.

RICHARD S. ECKAUS

Department of Humanities

Anthropology/Archaeology Program

For the Anthropology/Archaeology Program, 1988-89 has been a year in which a number of new initiatives got underway. Anthropologists teaching in the PhD program in the History and Social Study of Science and Technology (Associate Professor James Howe and Professor Jean Jackson) were very enthusiastic about the first year of the program, for which Anthropology/Archaeology is a sponsor, along with History and STS. Associate Professor Arthur Steinberg completed his first year as head of the Integrated Studies Program. Anthropology/Archaeology inaugurated a newly renovated and badly needed teaching laboratory. Hass-D subjects taught by A/A Program faculty, if not all heavily subscribed, drew high praise for their innovative creativity. And the Program's cultural anthropologists put together a faculty and graduate seminar on "Peoples and States: Ethnic Identity and Struggle," to be sponsored by the MIT Center for International Studies during 1989-90.

Program members gave talks at a large number of conferences and symposia, in sites from Yugoslavia (Professor Jackson) and Denmark (Visiting Assistant Professor Jonathan Wylie) to Oregon and New Mexico (Professor Howe). Professor Heather Lechtman gave the inaugural lecture, entitled "Old World-New World, Technologies of Art, Technologies of Power," in a special series sponsored by Archaeological Institute of America.

Articles by Program members were published or accepted during 1989-90 by journals as varied as Dialectical Anthropology, Pacific Studies, North Atlantic Studies, Annual Review of Anthropology, and Journal of Anthropological Research, as well as in a number of edited volumes. One notable example was an article by Professor Steinberg and Visiting Professor Wylie, "Counterfeiting Nature: Artistic Innovation and Cultural Crisis in Renaissance Venice," which has been accepted by Comparative Studies in Society and History. A majority of Program members currently have books in progress, and a monograph entitled Ax-monies and their Relatives is in press in a series published by Dumbarton Oaks. Written by Professor Lechtman and Dr. Dorothy Hosler with a colleague from outside MIT, it is the culmination of a major research project on their part.

Two new faculty members, Dorothy Hosler and Lisa Rofel, will be joining the Program as Assistant Professors in September of 1989. Both have been on post-doctoral fellowships since they were hired in the Spring of 1988. Professor Howe, who will be spending 1989-90 on leave in Oxford, is retiring as head of the Program, to be succeeded by Professor Jackson.

JAMES HOWE

Foreign Languages and Literatures Section

The current year of the Foreign Languages and Literatures Section (FLL) has been marked by continued scholarly and professional activity, a commitment to excellent teaching, and an intense involvement in the Humanities reforms underway at the Institute. In addition, FLL has received research support from the Consortium for Language Teaching and Learning and has continued its involvement with the Athena Language Project, which has acquired national recognition.

This year four books have been published by faculty and lecturers within FLL. Associate Professor Edward B. Turk's critical study of Marcel Carné, Child of Paradise: Marcel Carné and the Golden Age of French Cinema (Harvard University Press), discloses the incongruities between the director's aesthetic of poetic realism and his professed leftist sympathies. Associate Professor Suzanne Flynn has edited a volume with Wayne O'Neil, Linguistic Theory and Second Language Acquisition, (Reidel Press), in which two of her important articles are included. Lecturer Christopher Sawyer-Laucanno's portrait of Paul Bowles, An Invisible Spectator: A Biography of Paul Bowles, (Weidenfeld & Nicolson; Bloomsbury Press), illuminates his fiction and music in terms of his life. Lecturer Elena Semeka has co-edited a book with Institute Professor Morris Halle and the late Krystyna Pomorska, Semiotics and the History of Culture: In Honor of Jurij Lotman, Studies in Russian, Vol. II, (Slavic Publishers, Inc.), which is a definitive compilation of current approaches in semiotic theory. Other members of the faculty are pursuing on-going research in various areas resulting in numerous articles and books in progress. These include: Linguistics, Second and Foreign Language Acquisition (Professors Catherine Chvany, James Harris, Claire Kramsch, Assistant Professor Michio Tsutsui and Lecturer Ellen Crocker); Foreign Literary Studies (Professor Robert Jones, Associate Professors Isabelle de Courtivron, Elizabeth Garrels, and Margery Resnick and Assistant Professor Edith Waldstein); and Film and Media Studies (Associate Professor Michael Geisler).

The highlight of the year was the visit of the internationally known author, Günter Grass, who read excerpts from his new book, Zunge Zeigen (Show Your Tongue). FLL also hosted other guest lecturers, a film series and a German drama workshop. Professor Chvany received a medal for outstanding scholarly contributions to Russian Studies at the 10th International Congress of Slavists and Professor Kramsch received the National Nelson Brooks Award for the Teaching of Culture from the American Council on the Teaching of Foreign Languages.

The total enrollments (1751) are markedly down from the 1987-88 figure of 2024. The number of concentrators (total: 198), majors (10) has remained constant, while the number of minors totalled 17. Since this is a new program, future growth in FLL minors is expected. French still has the largest enrollments (405), followed by Spanish (327), Japanese (264), German (262), English as a Second Language (236), World Literature in Translation (221) and Russian (149). Thanks to the excellent quality of the teaching given both by faculty and lecturers, FLL subjects continue to receive some of the highest ratings in the Student Course Evaluation Guide.

Personnel changes this year include the departure of Associate Professor Geisler to Guilford College, Assistant Professor Katherine Crecelius for a career in international banking, and Assistant Professor Waldstein to the University of Iowa. Visiting Professor Margaret Sokolik joined the program in English as a Second Language in September and will be here for another year. Administrative Assistant Richard Larraga left in April and was replaced by Karen Booth who joins us from the treasurers office. Phyllis Gutterman became the Administrative Officer last August. Lecturers Gilberte Furstenberg and Douglas Morgenstern will be appointed to the rank of Senior Lecturer this coming academic year. Dean Ann F. Friedlaender will continue as Acting Head of FLL as the Section continues its outside search for a permanent Head.

ANN F. FRIEDLAENDER

History Section

The American historians were unusually peripatetic during the past year. After nine years as Head of the History Faculty, Professor Pauline Maier took sabbatical leave in the Fall and was supported in the Spring by an NEH Fellowship For College Teachers. She presented papers at professional meetings in Williamsburg, Houston, Claremont, and Madison, continuing her research on the impact of the American Revolution on American society between Independence and the Civil War; she will be on leave during the Spring of 1990 on a Guggenheim Fellowship. Associate Professor Michael McGerr, on leave in the Fall, served on the Program Committee of the Organization of American Historians in St. Louis and Cincinnati, and gave talks to MIT Alumni Clubs in Houston, Palm Beach, Falmouth, and Boston. Assistant Professor Sarah Deutsch who will be promoted July 1 to Associate Professor, spent the year on an NEH Fellowship at the National Humanities Center in Research Triangle Park, North Carolina.

Professor Robert E. MacMaster was invited to deliver a paper on Tolstoy at the X International Congress of Slavists in Sofia in September. Professor Bruce Mazlish chaired the Toynbee Prize Selection Committee and was himself elected to the Board of Trustees of the Rockefeller Family Fund. The Oxford University Press will publish his new book, "A New Science: The Breakdown of Connections and the Birth of Sociology" in September, 1989. Professor Harald Reiche gave three papers on historical astronomy, one of which will be published as a major article in the Transactions of the American Philological Society on the application of stellar phases to historical dating. Associate Professor William B. Watson edited a special Spanish Civil War issue of the Hemingway Review, wrote a feature piece on Hemingway's wartime dispatches from Spain for the Boston Globe and gave a paper at the "Hemingway in Idaho" conference on "The Dilemmas of Propagandist and Writer."

Associate Professor Philip Khoury combined his duties as Associate Dean with active scholarly enterprise, co-editing a major selection of studies on Tribes and State Formation in the Middle East in addition to three articles on Syrian political culture and the analysis of political leadership in the Middle East and North Africa. Associate Professor Peter C. Perdue delivered a paper at the Columbia University Seminar on Modern China and participated in the Asian Council Workshop at MIT. Instructor Robin Kilson introduced new subjects during the Spring Term on "The History and Culture of African Heritage" and on "Imperialism and Colonialism in International Relations."

The History Faculty is completing the design of a new full-year HASS-D subject on "The Last Hundred Years: Perspectives On Global History," to be introduced in September, 1990. Although the center of the syllabus is likely to be drawn from topics in the history of Atlantic Europe, roughly equal distribution is to be given to the United States and the Third World. The subject is also to include four to five lectures on the changing history of ecosystems under the impact of industrialization and imperialism. Assistant Professor Douglas Forsyth is to develop the main body of the syllabus during the Summer of 1989. Another new entry on the HASS-D in Historical Studies will be a subject on "Conspiracies, Strikes, and Popular Uprisings in American History," planned and jointly taught by Professors Maier and Robert Fogelson. Two options in the new program of Freshmen Advisor Seminars were offered in the Fall of 1988, one by Professor Perdue "From Asia to America," and the other by Professor Richard Douglas together with Warren Seamans, director of the MIT Museum, on "Topics in the History of MIT." Another innovation was developed by Associate Professor Arthur D. Kaledin, who reorganized the Pre-Thesis Tutorial into a series of group meetings

concerned with research techniques, preparation of bibliography, and the use of libraries and archives, leading to the writing of a long essay at the end of the seminar. Professor MacMaster offered the first History credit subject during IAP on "Classics of Social Thought and History," based on texts from the work of Aristotle, Locke, and Nietzsche, which attracted twenty-five students. During the second term Professor Watson offered a new subject, "Seminar in Historical Methods," for students pursuing a minor or major program in History, adding substance and structure to the undergraduate curriculum. The full major in History now consists of nine elective subjects, a cluster of four subjects from a second HASS discipline, the Pre-Thesis Tutorial, and either a thesis or a second long essay.

Members of the History Faculty continued to serve on a number of Institute committees. Professor Fogelson was appointed to the Faculty Policy Committee. Professor Kaledin continued to serve on the Institute Library Committee, the Policy Committee of the Experimental Study Group, and the Context Working Group chaired by Professor Francis Low. Professor Khoury was a member of the Executive Committee of the Center For International Studies, the Aga Khan Review Committee, and chaired the HASS-D Committee. Professor MacMaster continued his long service on the ROTC Committee. Professor Mazlish was a member of the Edgerton Award Committee, the Burchard Scholars Selection Committee, and co-chaired the planning group (with Professor Forsyth) for the lecture series on the French Revolution. Professor Perdue was a member of Science and Engineering Working Group, the Committee on Curricula, the Dibner Institute Planning Committee, and the HASS-D History Subcommittee. Professor Ralston was the IAP Coordinator for History, and Professor Watson was the UROP Coordinator and a member of the Committee on the Arthur Miller Lectureship.

Three resignations from the History Faculty were submitted this year: Professor McGerr to accept appointment at the University of Indiana, Professor Deutsch at Clark University, and Ms. Kilson at Bryn Mawr College. Professor Reiche resigned his position as Master of Baker House after nine years, where he will be succeeded by Professor Watson.

The historians, along with members of other Humanities faculties, owe a special debt of appreciation to I. Austin Kelly III, '26 for his on-going support of humanistic study at education in M.I.T. -- for his contribution of rare books to the Humanities Library, his gift of Hudson River paintings, and for the fund established in his name twelve years ago, nearly doubled by his additional contributions during the Spring of 1989. Mr. Kelly is unique in the continuity of his support of humanities at M.I.T.

Professor Douglas will be succeeded as Section Head by Professor Mazlish on September 1, 1989.

Richard M. Douglas

Literature Section

During the course of this past year, the Literature Faculty of the Department of Humanities registered or graduated 29 majors, 22 students enrolled in the new HASS minor, and 150 students proposed or completed a HASS concentration (not counting 15 students in the Film and Media program). During the same period, the total number of undergraduate students attending some subject in the program was slightly more than 1200, or about 100 students for each member of the faculty in residence. Granted that the figures for the HASS-minor introduce a new factor, one can nonetheless say that these numbers represent the commitment to instruction discharged by the section for some years now and that they will probably not vary significantly for some time to come.

The import of these numbers points to the perennial difficulty of the section, which lies in the area of staffing, which is particularly acute in the area of HASS-D enrollments. It is too early to say whether the recent reform in the distribution system may effectively work to shift the burden of HASS-D enrollments and so help to alleviate the difficulty. In the meanwhile, the section has acted to budget for fewer sections of distribution subjects while increasing emphasis upon second- and third-level subjects aimed at minors and majors, and it has made maximum use of cross-listing and non-literature faculty by negotiating syllabi across sectional and departmental lines, so that only a modest share of teaching next year will be accomplished by ad hoc appointments. At the same time, it is hoped that other initiatives going forward in the School will shift the emphasis of curricular planning within the section even further to advanced undergraduate teaching.

As for this year's accomplishments, the Literature Faculty maintained a high level of visibility in the professional world by a variety of publications, invited talks at universities, and papers delivered at professional conferences. Several members of the Literature Faculty were also active in editorial or consultational capacities for various funding organizations, journals and university presses. Two books were published by members of the faculty: Professor Peter Donaldson's work on Machiavelli and the Mystery of State (Cambridge University Press) and Associate Professor Theoharis Theoharis's Joyce's Ulysses: an Anatomy of the Soul (University of North Carolina Press). Four books were completed and accepted for publication: two collections of essays by Associate Professor David Halperin, one by his hand, the other under his editorship; a study of five contemporary Irish novelists by Associate Professor John Hildebidle; and Professor Irene Tayler's literary biography of the Bronte sisters. We should mention as well that the first volumes of a new series on media and popular culture have been published by Unwin and Hyman under the general editorship of Professor David Thorburn, and that Professor A.R. Gurney's play, The Cocktail Hour has been a long-running hit on Broadway since it opened in the Fall.

Articles by faculty members appeared in various journals, among them Dossier, South Atlantic Quarterly, Partisan Review, History and Theory, Quarterly Review, The Yale Journal of Criticism, Proceedings of the Boston Colloquium in Ancient Philosophy, Bulletin of the Shakespeare Association of America, and Harvard Library Bulletin. Essays by faculty members have been reprinted in book form in Classics: A Discipline in Crisis (University of America Press), On Whitman (Duke University Press), and Blake (MLA Press). Poetry and fiction by faculty members has appeared in Nation, Agni, Yankee, Beloit Poetry Journal, and elsewhere.

We are pleased to announce the promotions, effective as of July 1, of Associate Professors Halperin and Stephen Tapscott to the ranks of Full Professors, the award of tenure to Professor Hildebidle, and the appointment of Professor Theoharis to Class of

1943 Faculty Development Chair. We are also pleased to report the award of a grant in research from the Whiting Foundation to Professor Alvin Kibel and the award of a planning grant to Professor Ruth Perry from the Ford Foundation to establish a consortium for Women's Studies in the Boston/Cambridge area.

We conclude by reporting the Literature Faculty's continual involvement with a modest but remarkable experiment at the Institute. For the past three years, the Literature Faculty has offered a mini-seminar running intensively for five consecutive mornings during the month of June in some manageable area of literary studies and open to faculty from different schools at the Institute. This year's topic was a brief history of the short poem in English, conducted by four members of the Literature Faculty and one from the Writing Program. In the event, 47 faculty from the various Schools attended and derived, we believe, an enhanced sense of the possibilities of intellectual conviviality across fields and disciplines at MIT.

ALVIN C. KIBEL

Music and Theater Arts Section

Music and Theater Arts concluded its second year as a combined section, pursuing its mission to build as strong a structure for theater and dance as music now enjoys. Our new colleagues have joined us with energy and spirit in this enterprise.

We completed our first step in this direction with the appointment of Professor Alan Brody as Director of Theater Arts. His effect upon the theater program was immediate, beginning with the direction of Shakespeare's "A Winter's Tale" in October, followed by an expansion of the theater curriculum and the establishment of a minor in Theater Arts.

In recent years the music program has set as a long-range goal the integration of performance and the study of musical structure and history. Our curriculum has been built around the making of music, a goal not always found in music programs within liberal arts colleges. The inclusion of our gifted student performers in the classroom has been achieved in ever-increasing numbers. This year 1207 students enrolled in credit-bearing courses, with an additional 300 students participating in co-curricular performance activities directed by the Section. A strong interest in theoretical courses, leading ultimately to composition and advanced analysis, is now clear. The initial course in this sequence, 21.641 Harmony and Counterpoint I, a HASS-D subject, had enrollments of 107 students and could not satisfy further demand due to lack of classroom space.

The Section continues to be governed by a yearly rotation among five of the faculty, a system that has produced wide participation in the planning of our program while allowing the continuation of important careers in the professional music world. Associate Professor Jeanne Bamberger, distinguished theorist whose studies of cognitive processes in musical perception have won her international recognition, takes the chair for 1989-90.

With the rapid expansion of classroom enrollments, new courses and performance activities, space has been a continual problem for the past few years. The situation has been further heightened by the extreme lack of facilities for our new colleagues in Theater Arts. Our conviction that the performing arts at MIT belong together in function, spirit, and physical place has been understood by Institute administrators. This year the Section moved to redesigned quarters on the second floor of Building 14. Chief among the advantages were the establishment of a consolidated headquarters space, the creation of a Concerts office within that area, and expanded office space for our merged faculty. Rehearsal rooms for all aspects of the program, however, remain in short supply.

The availability of Killian Hall as an intimate recital hall has been a major addition to music facilities. The hall was the site of numerous chamber concerts this year by visiting artists and MIT faculty and students, including a new series of sixteen recitals in the spring semester by students selected by competitive audition to participate in the 21.658/59 Advanced Musical Performance under Professor Marcus Thompson.

Concerts sponsored by the Section continue to flourish, numbering 104 this past year. Programs in our Chapel series featured a variety of soloists and ensembles, both from the Boston area and abroad, performing music from a wide spectrum of historical eras. The series has firmly established itself with a dedicated core of regular subscribers.

The Guest Artist series brought to MIT the Lindsay, Manhattan, and Muir String Quartets, and the contemporary ensemble, Terra Australis, as well as MIT alumnus, John Miller, for many years principal bassoonist with the Minnesota Orchestra. All concerts were attended by large audiences from the Institute and the larger community. MIT music organizations had productive seasons. The MIT Symphony Orchestra under Professor David Epstein surveyed the music of Beethoven, performing the Fifth Symphony and the Fourth and Fifth Piano Concertos with graduate student soloists Marc Alain Ryser and Ruth Ying-Hsin Schindler respectively. The Boston Globe was particularly impressed with Ryser's gifts. The orchestra also performed and recorded song cycles by Professor Epstein and Senior Lecturer Edward Cohen, and late romantic Russian piano concertos with Abbott Ruskin for a Pantheon International compact disc.

In response to the increasing number of students seeking admission to the MIT Choral Society, the Society, a community chorus directed by Senior Lecturer John Oliver, was replaced this spring by a Concert Choir composed entirely of students selected by audition. The group gave its debut concert in May with a performance of Bach's St. John Passion.

Lecturer John Corley celebrated his 40th anniversary as Founder and Conductor of the MIT Concert Band with a gala concert and reception in May. Alumni of the band were invited to return and participate in the concert. The MIT Festival Jazz Band won an Outstanding Performance Award at the Boston University College Band Festival and participated in the 1989 Notre Dame Jazz Festival, the country's leading college jazz festival, where trumpeter David Ricks won an award for outstanding performance.

With the extended residencies of guest directors Steve McConnell and Patrick Swanson, Theater Arts initiated the practice of bringing professional guest artists to the campus as master teachers and practitioners. Mr. McConnell directed the Shakespeare Ensemble's production of Henry V, while Mr. Swanson directed an adaptation of Dylan Thomas' screenplay, The Doctor of the Devils, for the Dramashop. The year also included two evenings of one-act plays, a series of student written pieces including Dramashop's

IAP production of AHAL, a theater piece developed from student improvisation. Theater Arts coordinated and produced this year's Abramowitz Lecture, Zoe Caldwell's one-woman show, Come a'Waltzing With Me.

The Dance Workshop continued its tradition of student and professional performances in dance. It will bring Beth Soll & Company to campus as artists in residence beginning in 1989-90. Members of that company choreographed and performed in the 1988-89 Dance Workshop recitals.

A number of seniors majoring in music produced unusually fine work. Kenneth Goodson won the Sudler Prize for his outstanding performances as a singer. His senior recital was one of the major events of the year. Jackson Bross won the Edgerton Award for the high level of his work in music. His senior thesis, a string quartet, was viewed with distinction and placed in the MIT music archives.

Faculty and staff continued to be professionally active. Professor Epstein spent a period as visiting professor at the Institute for Medical Psychology of the University of Munich and at the Manfred Eigen Seminar in Klosters, Switzerland. He is an editor and contributor for the book Beauty and the Brain: Biological Aspects of Aesthetics (Birkhaeuser, 1988). Professor Stephen Erdely read a paper on "Identity Expression through Traditional Music" at the Society for Ethnomusicology meetings in Arizona, and prepared for the hosting of the International Conference in Ethnomusicology at MIT in the Fall of 1989. Professor John Harbison had performances of chamber works at Lincoln Center and his Concerto for Double Brass Choir and Orchestra by the Los Angeles Philharmonic, which commissioned it. Other commissions included the Juilliard String Quartet and Pittsburgh Chamber Music Society. Professor Thompson performed at festivals in Alaska, Los Angeles and Seattle, with the Chamber Music Society of Lincoln Center, and at the International Viola d'Amora Congress in Stuttgart. He was a judge in the Concert Artists Guild and Carnegie Hall International American Music competitions.

Associate Professor Lowell Lindgren chaired sessions at congresses in Durham, England and the American Musicological Society in Baltimore. He published a number of articles in various journals during the past year, and is currently writing articles for The New Grove Dictionary of Opera and the Royal Musical Association Research Chronicle. Assistant Professor Peter Child's Estrella received its premiere by the Cantata Singers to wide acclaim, following upon a London performance of his Ensemblance. Seven of his works were published this year.

Senior Lecturer Cohen, who was Visiting Associate Professor at Brandeis University, had his works performed by Boston University's Alea III, by the MIT Symphony Orchestra, and on Brandeis University's chamber series. He completed a one-act opera, Bezhin Meadow, based on a story by Turgenev. Senior Lecturer Oliver, director of the Tanglewood Festival/Boston Symphony Orchestra Chorus, prepared the chorus for performances and recordings of the Beethoven Ninth Symphony, Strauss Elektra, Haydn The Seasons and Ravel Daphnis and Chloé. His John Oliver Chorale gave Boston concerts of works by Vaughan Williams, Ives, Bach and Mozart.

Lecturer Pamela Ambush toured Europe with the Steve Reich and Musicians Ensemble. Lecturer David Deveau presented an all-Beethoven concert at MIT that won high critical acclaim from the Boston Globe. His schedule included concerts at the Kennedy Center in Washington, D.C. and New York. Lecturer Mark Harvey published articles on jazz and religion in Theology Today, Soundings, and Religion and Intellectual Life. Lecturer Martin Marks was featured on the University of New Mexico International Cinema Lecture Series, discussing the Shostakovich film score for The New Babylon in conjunction with the New Mexico Symphony Orchestra.

Our colleagues in Theater Arts and Dance were equally busy. Professor Brody won the Lois and Richard Rosenthal Award for his play, Invention for Fathers and Son, produced at the Cincinnati Playhouse in the Park. Senior Lecturer Beth Soll premiered Dreams and Illusions as part of the Mass Moves Festival and served on the advisory panel for The Artists Foundation.

Several important appointments and promotions were confirmed for next year. Professor Ellen Harris of the music faculty of the University of Chicago will join the MIT music faculty as Professor of Music, in addition to her appointment as Associate Provost for the Arts. Lecturer Marks' appointment as Assistant Professor of Music, and Professor Bamberger's promotion to full Professor will take effect on July 1, 1989.

Two long-time colleagues, Lecturer Robert Scanlon and Affiliated Artist Paul Orgel left our faculty at the end of the school year.

David Epstein

Writing Program

The Writing Program performs a vital teaching service at the Institute. The Program's curriculum maintains a depth and balance appropriate for the diverse student population. The current undergraduate subjects in expository writing, creative writing, and science and technical writing draw a steady enrollment of students at all levels, advanced and beginning alike. Many subjects satisfy either Phase One or Phase Two of the Institute Writing Requirement. The cooperative writing subjects for both undergraduates and graduate students, within the various engineering departments, continue to hold their enrollments. Undergraduate cooperative subjects now exist within several departments in the School of Science. The summer session course 21.10s Communicating Technical Information was again popular with many students from industries throughout the world. The Annual Conference on Writing for the Computer Industry, with Lecturer Edward Barrett as director, was a big success in its second meeting at MIT.

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 the craft of writing. At "An Evening of Poetry with Robert Pinsky," the poet Pinsky gave an impassioned reading of his poetry. The acclaimed literary scholar, Professor Arnold Rampersad, spoke on "Biography and Langston Hughes," recounting his experience researching and writing his major two-volume work *The Life of Langston Hughes*. The MIT and larger communities responded enthusiastically to the events.

Four faculty members have released new books this year. Visiting Writer Janette Hospital published her novel *Charades* (Toronto: Bantam, 1989). Professor Elzbieta Ettinger (Chodakowska) published her second novel *Quicksand* (London: Pandora Press, 1989). Associate Professor James Paradis (with George Williams) has recently published *Evolution and Ethics: T.H. Huxley's Evolution and Ethics With New Essays on Its Victorian and Sociobiological Context* (Princeton: Princeton University Press, 1989). Lecturer Edward Barrett published *The Society of Text: Hypertext, Hypermedia, and the Social Construction of Information* (Cambridge: MIT Press, 1989).

Associate Professor Harriet Ritvo won a Guggenheim Fellowship and a Fellowship from the National Endowment for the Humanities and will be on leave for the coming year. The novelist David Bradley will join the program for the fall term as Visiting Professor.

Department of Linguistics and Philosophy

Research: Linguistics

Linguistic research this year included studies of the comparative grammar of the Misumalpan languages of Nicaragua and Honduras; obviation and chaining constructions in various native American languages; the lexicon and quantification in Warlpiri; stress theory and studies in the nature of word formation and morphology; problems in the foundations of linguistics, including the scope and validity of "externalist" critiques in philosophy of language and mind, and associated ideas concerning the theory of meaning in natural language.

Research: Philosophy

Research in philosophy covered topics from a variety of fields. Among them are: proofs of the incompleteness of arithmetic; foundations of set theory; unrestricted quantification in formal languages; the redundancy theory of truth; philosophical development; topics in the philosophy of mind -- in particular, mental causation and so-called narrow content; rational egoism; the role of ethical norms in social explanation; rights, and their relations to risks, liabilities, and responsibilities; the philosophy of Santayana; topics in the history of 17th century philosophy, with special attention to the philosophy of Spinoza.

Publications

Among Institute Professor Noam Chomsky's publications this year was Generative Grammar: Its Basis, Development and Prospects (Studies in English Linguistics and Literature, Kyoto University of Foreign Studies). Professor Wayne O'Neil is co-editor (with Associate Professor Suzanne Flynn of Foreign Languages and Literature) of Linguistic Theory and Second Language Acquisition (Kluwer Academic Publishers, Dordrecht, The Netherlands); and Assistant Professor David Brink's book Moral Realism and the Foundation of Ethics was published by Cambridge University Press.

Honors and Awards

Ferrari P. Ward Professor Kenneth Hale and Professor Judith Jarvis Thomson were elected Fellows of the American Academy of Arts and Sciences. Institute Professor Morris Halle and Laurance S. Rockefeller Professor Thomas Kuhn received honorary doctorates from Brandeis University and Ohio Wesleyan University, respectively.

Leaves of Absence

On sabbatical leave for the year, Professor Ned Block was a visiting fellow at Birkbeck College, University of London, and lectured at many universities including Oxford, Cambridge, Sussex, Edinburgh, the International School for Advanced Studies in Trieste, and the Center for Research in Applied Epistemology in Paris.

In the spring term, Associate Professor Joshua Cohen was a visiting professor in the Philosophy Department at Princeton.

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Personnel

With regret we announce the resignations of two members of the linguistics faculty, Associate Professors Richard Larson and Donca Steriade. Professor Larson will join the linguistics faculty at SUNY, Stony Brook, and Professor Steriade will take a position in the Linguistics Department at UCLA. Both have been valuable colleagues, and we wish them well.

We are pleased to announce the appointment of Associate Professor Irene Heim, who will join the linguistics faculty and teach primarily in the area of semantics.

We were fortunate to have the services throughout the year of Professor Michael Kenstowicz (linguistics, University of Illinois, Urbana) and Associate Professor Georges Rey (philosophy, University of Maryland) as visiting faculty. Both contributed greatly to the intellectual life of the department through teaching, thesis advising, and informal conversation.

Finally, as I retire as department head after four years in that position, I wish to thank my colleagues, students, and office staff for the cooperation and goodwill they have shown me. And I wish Professor Wayne O'Neil well in his role as Acting Head for the coming year.

RICHARD L. CARTWRIGHT

Department of Political Science

The members of the Department of Political Science devoted major efforts in the academic year 1988-89 to planning faculty recruitment strategies for the next five years. As in all major political science departments in the country, these will be years in which senior distinguished figures will be retiring and have to be replaced, from a pool reduced by years of poor job prospects in the field. The result is already visible all across the country: increased competition for outstanding scholars in all ranks, job mobility, and rapidly escalating salaries. In order to protect faculty quality and the international reputation of the Department, we need to spread our hiring broadly across various ranks and fields and to focus particularly on maintaining core strengths in political science as well as in the special fields that have characterized the MIT Department. As a result of our recruitment efforts in 1988-89, Professor Ronald Dore, a senior and highly distinguished scholar on Japan and on the political economy of advanced industrial societies, will be joining the Department as Adjunct Professor. Margaret Burnham, formerly Boston Municipal Court Judge, and a practicing attorney, will join us as Lecturer, replacing Senior Lecturer Louis Menand III, who retired in 1988. Professor James Jennings, Senior Fellow at the Trotter Institute, will visit the Department for the year 1989-90. Assistant Professor Charles Stewart will be promoted to Associate Professor. Another change in the Department this year was Professor Donald L.M. Blackmer's completion of 7-1/2 years as Head, and return to teaching and research in the Soviet field. Professor Suzanne Berger has become Department Head. Associate Professor Richard J. Samuels is Associate Head.

We continue to be successful in attracting strong graduate students, despite our inability to match most of the other major departments in our financial aid packages. The graduating PhD candidates have fared well in this year's job markets, receiving jobs at Harvard, Yale, Chicago, Georgetown, Rand, and elsewhere. We are proud that one of our recent PhDs, Victoria Hattam (currently Assistant Professor in the Department of Political Science, Yale) was just awarded the E.E. Schattschneider Award for the best dissertation in the field of American politics. Our undergraduate enrollments and majors continue to grow, with 46 majors this spring, a substantial increase over 21 in 1984-85.

The scholarly production of the faculty remains strong. A complete list of the major publications by the faculty is too long to reproduce here; we note only recent books and those that will appear before the end of 1989. Assistant Professor Jonathan Fox has contributed to and edited a volume, The Challenge of Rural Democratization in Developing Countries, on overcoming obstacles to democracy in third-world rural societies. Professor William E. Griffith's book, Central and Eastern Europe: The Opening Curtain, has appeared, and one on Europe, "1992: Differing US and European Community Responses," will be published by the end of the year. Professor Willard R. Johnson's work, "West African Governments and Volunteer Development Organizations: Priorities for Partnership," will appear this fall. Assistant Professor Steven Miller has co-edited three volumes that appear this year: Soviet Military Policy (with Sean Lynn-Jones and Stephen Van Evera), The Navy and Nuclear War (with Charles Glaser), and Nuclear Arguments: The Major Debates on Strategic Nuclear Weapons and Arms Control. Professor Charles Sabel, together with Marino Regini, published Strategie di riaggiustamento industriale. Professor Sapolsky's book, "Science and the Navy: The History of the Office of Naval Research," will be forthcoming by the end of the year from Princeton University Press. Associate Professor Charles Stewart's book, Budget Reform Politics: The Design of the Appropriations Process in the House, 1865-1921, has been published by Cambridge University Press. Assistant Professor Richard Valelly's work, "Radicalism in the States: The Minnesota Farmer-Labor Party and the American Political Economy," will

be coming out in July. Professor Myron Weiner's "The Indian Paradox: Essays in Indian Politics," will be published in August. Professor Berger was a co-author of the MIT Commission on Industrial Productivity's study, Made in America: Regaining the Productive Edge.

The contributions of the political science faculty were recognized in a variety of honors they received this year. Professor Eugene B. Skolnikoff was presented with the Order of the Rising Sun, Gold Rays ribbon by the Japanese government. Professor Lincoln P. Bloomfield was awarded the 1988 EDUCOM/NCRIPTAL prize for "Distinguished Software" in Political Science for CASCON (Computer-Aided System for Analysis of Local Conflicts). Associate Professor Barry R. Posen was elected a member of the Council on Foreign Relations, and Professor Miller was granted one of the Council's International Affairs Fellowships. Two members of the faculty received special citations for outstanding teaching: Associate Professor Joshua Cohen was the recipient of a Graduate Student Council Teaching Award. Professor Stewart was presented with the Everett Moore Baker Memorial Award for Excellence in Undergraduate Teaching. Professor Stewart has also been chosen as a National Fellow for a research year at the Hoover Institution, Stanford University for 1989-90. Professor Hayward R. Alker, Jr. lectured this spring in Uppsala and Stockholm as the first Olof Palme Professor, an award established in memory of the late Prime Minister of Sweden. Assistant Professor Richard Locke, who holds a joint appointment in the Sloan School of Management, was named to the IRI Career Development Chair.

Members of the Department were highly visible in the profession as well, with Professor Lucian W. Pye serving as President of the American Political Science Association (APSA) in 1989-90. Professor Michael Lipsky was elected a member of the Council of the APSA, and Professor Berger finished a term on the Editorial Board of the association's journal, the American Political Science Review. Professor Pye was also active in a variety of other associations, serving as Vice Chairman, National Committee on US-China Relations; trustee of the Asia Foundation; Board of Director, Association of Asian Studies; and others. Professor Berger is a member of the Executive Committee, Social Science Research Council. Professor George W. Rathjens is chairman of the Council for a Livable World and the Foundation for International Studies on Peace and Security. Professor Johnson co-chaired the annual meeting of the Association of Concerned African Scholars. Professor Alker is Vice President Elect of the International Studies Association, and headed the American delegation to the ISA World Assembly in Williamsburg.

Within the Institute, political science faculty collaborated in projects that ranged across virtually all of MIT's concerns. Professor Nazli Choucri has initiated a faculty seminar on the global environment and on global security, and is involved planning Institute-wide activities on these issues. As Director of the Center for International Studies, Professor Weiner has developed new seminars and research, drawing in faculty from various parts of the Institute. The dynamism of the Center, under Professor Weiner's leadership, was reflected in the success of the program jointly developed with the Industrial Liaison Program on the technology development process in international comparative perspective. The symposium with 22 speakers, mostly MIT faculty, was held in Kresge Auditorium on April 25-26, with about 180 participants.

Another promising new initiative is an effort, jointly with the Sloan School of Management, to create new regional "minors" for MBA students at Sloan. Professor Samuels is participating in that committee, which is headed by Dean Lester J. Thurow. Professor Samuels heads the MIT-Japan Program in Science and Technology, which this year was recognized by a special report of the Congressional Office of Technology Assessment as a model for applied Japanese studies in the United States. In 1989, this program,

which is sending students in science and engineering to internships in Japanese factories, laboratories, and offices, expanded to include management students from the Sloan School. Assistant Professor Ellen M. Immergut organized a year-long seminar on Women and Politics, with guest speakers from around the country.

The Defense and Arms Control Studies Program continues to be a focus for collaboration between members of the Political Science Department and faculty from other parts of the Institute. Professor Jack Ruina stepped down this year as director of the program, and Professor Sapolsky replaced him. Associate Professor Stephen M. Meyer initiated a new activity for the working group on Soviet defense with the publication of a regular series of newsletters on current topics in Soviet security, Soviet Defense Notes.

One of the distinguishing features of the MIT political science group is an active participation in public policy analysis and debate. Professors Meyer, Samuels, and Berger testified before various Congressional committees this year. While requests to our faculty for advice and analysis from officials at all levels of government are very frequent, it was unusual when one of the faculty, Professor Meyer, privately briefed President Bush soon after he came into office. Professor Samuels served as member of the Congressional Office on Technology Assessment Panel on Defense Technology Base, and also as a member of a National Academy of Sciences Committee on Japan. Professor Lipsky was a member of the National Academy of Sciences Committee on the Status of Black Americans, whose report will be issued in July, 1989. Professor Sabel has been working with state agencies in Massachusetts, Michigan, and Pennsylvania to develop new training programs and plans for collaborative R and D for smaller firms.

SUZANNE BERGER

Program in Science, Technology, and Society

The last year saw changes in the Program in Science, Technology, and Society (STS) that will shape the Program in years to come. Among these were continued development of science and technology policy studies within the Program, a \$5 million challenge grant from the Knight Foundation for the Science Journalism Fellowship Program, the successful inauguration of the new doctoral program, and an enlarged set of activities in science and technology studies.

NEW ACTIVITIES

Science and Technology Policy Studies

Science and technology policy studies, long a priority for the Program, achieved greater strength during the last year. Theodore Postol, a leading expert on military technology and national security policy, will join the full-time STS faculty next year as Professor of Science, Technology and National Security Policy. His appointment will also strengthen the ties of STS with the Defense and Arms Control Studies Program in the Center for International Studies. Dr. Albert Wheelon served as Visiting Professor of Science, Technology, and Policy during the spring term, lecturing widely at MIT on space policy. All of this year's five Mellon Fellows focussed on science and technology policy issues such as nuclear regulation, environmental policy, industrial productivity and arms control. Associate Professor Richard Lester (Nuclear Engineering) taught a seminar on Industrial Productivity that grew out of his work as Director of the MIT Commission on Industrial Productivity. Ms. Margarita Crocker, a Mellon Fellow this year, will next year be a Post-doctoral Associate in the Program, jointly funded by the School of Humanities and Social Science and the Department of Nuclear Engineering, where she will teach the graduate course on nuclear policy. Professor Carl Kaysen and Professor Leon Trilling, taught a summer school course for MIT alumni on Science and Technology Policy. Most of the Political Science graduate students in Science, Technology and Public Policy are now affiliated with and housed in STS. Combined with the pre-existing work of STS faculty on policy issues, these new developments reflect the Program's commitment to strengthening science and technology policy studies at the Institute.

Knight Science Journalism Fellowship Program Grant

The Knight Foundation, which last year granted the Knight Science Journalism Fellowship Program \$3.25 million for long-term operating expenses, in June announced a \$5 million challenge grant to MIT for the endowment of the journalism program. The generous terms of this grant, together with the vigorous leadership of Senior Research Associate Victor McElheny, Director of the Knight Program, make this an extraordinary opportunity to place MIT's work in the public understanding of science and technology on a permanently secure financial footing.

Doctoral Program

The Doctoral Program in the History and Social Study of Science and Technology, a collaborative venture of STS, History, and Anthropology, had its first and successful year. Four students entered the program in September. For the coming academic year, the program has attracted five outstanding students, all of whom had excellent offers of support from other major programs. The Ph.D. program's ability to compete head-on with older and more established programs, despite extremely limited resources for fellowships, encourages the hope of creating the best program in the country.

Forum for Science and Technology Studies

The STS Program also expanded its activities as catalyst and sponsor of activities in science and technology studies at MIT. Two major projects culminated in public conferences this year. For the last two years, the Program has been collaborating with the American Academy of Arts and Sciences

and with its journal, Daedalus, on a major study of AIDS. That effort led this February to a public symposium on "AIDS: Long-term Prospects" in honor of Robert Morison, M.D., and to two issues of Daedalus on "Living with AIDS." An eight-year project on Soviet Science and Technology, directed by Professor Loren Graham and funded by the National Endowment of Humanities, the Laboratory for Computer Science, IBM, the Carnegie Corporation, and other foundations, concluded with a three-day conference at MIT this May. Twenty-eight papers from the project will be published by Harvard University Press in 1990 in a volume edited by Professor Graham.

Other new Program activities included the spring semester series on the Social Study of Science and Technology, led by Professor Charles Weiner, which brought four distinguished scholars to MIT for two days each to discuss recent work in the sociology of science. A monthly Newsletter was inaugurated last fall, containing short articles and news of the Program. This spring, a series of Working Papers was started; the first 11 papers will be available in the fall of 1989.

CONTINUING ACTIVITIES

The Program's undergraduate curriculum was extensively revised. New guidelines were developed to define faculty teaching responsibilities. Faculty effort was concentrated on Context and HASS-D subjects. Three Context subjects and three HASS-D subjects were offered this year. An STS minor was also developed. Undergraduate enrollments did not change significantly.

The STS graduate students and the Political Science-STS graduate students ran a biweekly Graduate Student Seminar series, with research presentations by students, faculty, and fellows. Professor Kaysen organized the STS Monday Luncheon Seminar Series, in which 24 speakers from inside and outside MIT spoke on topics ranging from problem solving in the nuclear power industry to communication satellites as an international trade issue to artificial intelligence. The STS Faculty-Student Workshop, organized by Professor Leo Marx, had a successful second year. These monthly workshops gave STS faculty and students a chance to present work in process, followed by informal discussion among faculty and students.

FACULTY AND VISITING SCHOLARS

Assistant Professor Lily Kay will join the STS faculty next fall. Currently Assistant Professor at the University of Chicago, she will bring an unusual combination of inside knowledge of modern molecular biology acquired as a research scientist at the Salk Institute, together with distinction as an historian of science.

Activities of individual faculty members were varied. Associate Professor Louis Bucciarelli spent his sabbatical year at the Center for the Sociology of Innovation at the Ecoles des Mines (Paris), where he completed a draft of a book on non-technological factors in engineering design. Assistant Professor Deborah Fitzgerald taught a new HASS-D subject, "Technology in American History," and gave papers at the History of Science Society and at a conference on "Women and the Transition to Capitalism in Rural America." She is a member of the Schumann Prize Committee of the History of Science Society. Professor Graham's recent work, Science, Philosophy, and Human Behavior in the Soviet Union, once banned in the Soviet Union, will be published in Russian translation in 1990 by the publishing house of the Communist Party of the USSR. Professor Kaysen's work as Chairman of the Editorial Advisory Board at WGBH culminated in a 13 part television series on PBS this spring entitled War and Peace in the Nuclear Age. Professor Kaysen published an article this spring in Annals of the American Association of Political Science entitled "Can Universities Cooperate with the Defense Establishment?" and continued work on his book on the militarization of American foreign policy. Professor Kenneth Manning continued his able leadership of the Writing Program and his study of the role of blacks in American medicine. Professor Marx lectured widely and published "The Case for Inter-Disciplinary Studies" in National Forum, Spring, 1989. Senior Research Associate McElheny continued his vigorous leadership of the Knight Program, which next year expects to have

12 Fellows in residence. Assistant Professor Lisa Rofel, on leave, worked at the Center for Chinese Studies at the University of California, Berkeley, on her study of industrial life and ideology in contemporary China. Professor Merritt Roe Smith was this year President of the Society for the History of Technology; he was on leave the second semester at the University of Pennsylvania to study problems in 19th century American history. Associate Professor Sherry Turkle, on leave all year, completed her study of Project Athena with Professor Donald Schon (Urban Studies and Planning) and, with the support of a grant from the MacArthur Foundation, continued her exploration of the role of computers in the Soviet Union. Professor Weiner continued his work on biotechnology while on leave the first term and lectured on his research at such institutions as the Smithsonian, University of California at Davis and Pennsylvania State University.

The Program continued to provide a home for a number of Visiting Scholars. Present for part or all of the academic year were: Dr. Joan Bromberg, Director of the Laser History Project; Dr. Jill Conway, President Emerita of Smith College (Visiting Professor in the School of Humanities and Social Science spring term), published her autobiographical work, The Road from Coorain, this year to widespread critical acclaim; Dr. Richard Fink, Dean of the Faculty and Professor of Chemistry at Amherst College; Mr. Hakon Finne, Research Scientist at the Institute of Social Research in Industry in Trondheim, Norway; Dr. Rafael Pardo, Associate Professor of Theory of Organization at the Complutense University of Madrid, Spain; Mr. Dennis Sebian, Project Manager, Boston Water and Sewer Commission; Professor James Wallace, Department of Mechanical Engineering, University of Maryland; Dr. Frederic Wien, Vice Chairman of Senate and Professor of Social Work at Dalhousie University in Halifax, Nova Scotia.

After five years of outstanding service to the Program, Administrative Officer Rhea Epstein resigned. She will be replaced by Ms. Judith Stein, currently Area Administrator for the Management Science Area of the Sloan School.

KENNETH KENISTON

Center for International Studies

SEMINAR SERIES AND WORKSHOPS

Leading activities of the Center for International Studies during the academic year 1988-89 were the various seminar series sponsored and co-sponsored by CIS, several of which have become well-established over the years and continue to attract speakers and attendance from the U.S. and abroad. The Emil Bustani Middle East Seminars, chaired by Associate Professor Philip Khoury of the History Faculty, completed its fourth year of presenting experts on Middle Eastern affairs. The Institutional Perspectives on Third World Development Seminar, sponsored jointly with the Department of Urban Studies and Planning under a grant from the MacArthur Foundation and chaired by Professor Judith Tandler (DUSP), focused on changing dynamics of the state, market, and non-governmental institutions in the development process. To mark its twenty-fifth year the Joint MIT-Harvard Seminar on Political Development (JOSPOD) looked at what has been learned about political development during the past quarter of a century. The seminar was chaired by Professors Myron Weiner, director of CIS, and Samuel P. Huntington of the Center for International Affairs, Harvard University. The Inter-University Seminar on International Migration, supported by the Sloan Foundation and chaired by Professor Weiner, continued to invite speakers on a wide range of subjects in the area of international migration. A series of informal noontime seminars in Political Economy was organized by Assistant Professor Richard Locke (Political Science and the Sloan School of Management). The Boston University-MIT-Harvard South Asia Seminar continued to bring members from the Boston area to exchange information and ideas with speakers from South and Southeast Asia. The Women and Politics seminars, cosponsored by CIS, the Department of Political Science and the Women's Studies Program at MIT, considered the impact upon women of political issues. A series of four workshops supported by the Ford Foundation and entitled The State and the Restructuring of Society in Afghanistan, Iran and Pakistan brought international scholars together for discussions of recent changes in those three states. Each workshop dealt with a separate aspect of current events: "Political Elites and the Restructuring of the Political Order;" "The State and the Political Economy of Redistribution;" "Women and the State in Afghanistan, Iran and Pakistan;" and "Transforming Political Cultures: Afghanistan, Iran and Pakistan." A new series, the Asian Council Workshops, began in the spring term with the theme, "Technology and Development in Asia." The series is organized by Associate Professor Peter Perdue (History Faculty). Jointly sponsored by CIS and the MIT Anthropology/Archaeology Program and organized by Professor Jean Jackson and Associate Professor James Howe, the first meeting of another new series, "Peoples and States: Ethnic Identity and Struggle," was held in the spring. The series will continue in 1989-90. Several special seminars brought a diverse group of scholars and political figures to CIS and attracted people from the larger community as well as academics: notable among these was a visit by the leader of the Mexican National Democratic Front (FDN), Cuauhtemoc Cardenas.

The CIS Soviet Studies Working Group, under the leadership of Associate Professor Stephen Meyer (Political Science), organized a one-day workshop on "Soviet Policy in the Third World." Assistant Professor Jonathan Fox (Political Science) conducted a three-day meeting entitled "The Challenge of Rural Democratization in Developing Countries." In April the CIS and the MIT Industrial Liaison Program presented a two-day meeting at Kresge Auditorium, chaired by Professor Weiner and entitled, "The Technology Development Process: an International Comparative Perspective."

DEFENSE AND ARMS CONTROL

The Defense and Arms Control Studies Program continued to maintain a diverse research effort. Research carried out by faculty in the Program dealt with such topics as: nuclear weapons; technical policy issues (Professor Jack Ruina, Electrical Engineering and Computer Science); nuclear weapons proliferation, the greenhouse effect (Professor George Rathjens, Political Science); Soviet defense and arms control doctrine and the Soviet style of decision-making on weapons procurement and deployment (Associate Professor Meyer); the institutional and organizational history of SDI and analyses of the weapons procurement process (Professor Harvey Sapolsky, Political Science); avoidance of escalation from conventional to nuclear warfare (Associate Professor Barry Posen, Political Science); and US defense and arms control decision-making, naval strategy, and naval arms control with particular focus on NATO's Northern Flank and the Arctic (Assistant Professor Steven Miller, Political Science). Dr. Marvin Miller (Senior Research Scientist in the Department of Nuclear Engineering and the Center for International Studies) continued his research in nuclear proliferation. Research Associate Dr. William Durch worked on European arms control issues. Post-doctoral Fellow Dr. Lisbeth Gronlund (Mellon Fellow, Cornell University) did research in the area of tactical nuclear weapons in Europe, and Post-doctoral Fellow Dr. Benjamin Miller conducted research on US-Soviet collaboration in managing third world conflicts. Thirty-one graduate students were associated with the Program in 1989-90. To date 41 men and women have received their Ph.D's in political science with a specialization in Defense and Arms Control Studies.

The Defense and Arms Control Studies Program also conducted the seventh MIT-Harvard Summer Workshop on Nuclear Weapons and Arms Control in June of 1988 for faculty at US and European colleges and universities. These workshops, funded by the Alfred P. Sloan Foundation, have contributed to expanding the teaching of arms control and defense policy issues throughout the country. On

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the occasion of the twenty-fifth anniversary of the Limited Test Ban Treaty, in November of 1988, the Program hosted a conference which drew together former Executive Branch officials who had been involved in test ban negotiations, scientists who were or are now involved in nuclear weapons work, and non-governmental analysts and researchers concerned with nuclear testing today, to reflect on the significance of the first major arms control treaty between the United States and the Soviet Union. In the spring of 1989 a third conference on "Nuclear Powered Submarines in Non-Nuclear Weapons States" drew participants from western Europe, South America, India, Canada, and the United States. The Program's work on defense and arms control policy is supported by the Carnegie Corporation, the Ford Foundation, the Hewlett Foundation, the Ploughshares Foundation, the Sloan Foundation, and the US Department of Defense. Support is also provided by MIT through its Fund for International Security and Arms Control.

MIT JAPAN PROGRAM

The MIT Japan Program has grown dramatically this past year. The number of students sent to Japan as interns has increased from 18 to 43. In addition the Program, in cooperation with the Sloan School of Management, will send management students to Japan starting in September 1989. Currently more than 130 students study the Japanese language at MIT. The Program also sponsors a Technical Japanese Workshop for Computer Scientists and Engineers which in its second year continues to be headed by Professor David Mills, Department of East Asian Languages of the University of Pittsburg. The Japan Program hosted a series of meetings of Japanese and American professionals from government, industry and academia to examine the Japanese technology process. In addition the Program co-sponsored a meeting with the Office of Technology Assessment on the MIT Japan Program which resulted in an excellent citation of the value of the Program in OTA's subsequent report to Congress. The Program also co-sponsored meetings with several Japanese agencies including the Productivity Center and the Agency of Industrial Science and Technology. Finally, with the American Association the Program co-sponsored a meeting which brought together alumni of the Program and companies doing business with Japan.

Program director Associate Professor Richard Samuels (Department of Political Science) is doing research on the Japanese Aerospace Industry. Associate Professor Eleanor Westney, Associate Director, is studying changes taking place in Japanese research and development laboratories. Michael Chinworth (Sloan School of Management), Director of Research, directs the Joint Study on Trade, Finance and Technology in East-West Economic Relations, a bi-lateral study group consisting of U.S. and Japanese business representatives dedicated to developing a comprehensive perspective of these issues within and between the two countries. Finally, the Program also runs a number of activities within MIT: a modern Japanese movies series, a monthly newsletter, a weekly Japanese lunch table, a Japanese reading room, a modern Japanese movie series, a monthly seminar on Japanese science and technology, and a retreat to prepare interns going to Japan. The Program is supported by the Japan Foundation, the US-Japan Friendship Commission, the Cornelius Vander Starr Foundation, the Hitachi Foundation, the National Science Foundation, and 14 corporate sponsors.

OTHER ACTIVITIES

Professor Weiner, director of the Center, acting as chairman of the Japanese Endowment Committee, announced the award of six grants to MIT researchers in the area of international energy and related technology policy. The Fund was established in 1980 by a gift to the Center from the Japanese Ministry of Foreign Affairs. The Center also acts as the MIT liaison for the Luce Foundation's annual Luce Scholar award, which enables recipients to spend a year in Asia while working in their own field. One award was granted to an MIT alumnus by the Foundation in 1989. This year the Center, in cooperation with the department of Political Science and UROP, initiated a summer research fellowship program to enable MIT undergraduates to do international and comparative research abroad; three students were granted fellowships for the summer of 1989.

For the third year the Center for International Studies conducted Seminar XXI: Foreign Politics and the National Interest, directed by Professor Suzanne Berger (Political Science). Seminar XXI is an educational program for senior military officers, government officials, and executives in the national security policy community. The seminar meets monthly, with each session focusing on different ways of analyzing the politics of other countries. The aim of the program is to develop in the future leadership of the national security community new analytical skills for understanding foreign countries by widening the range of possible explanations for the motives and behavior of our allies and rivals. The seminar is now self-supporting with organizations sponsoring fellows in Seminar XXI paying a program fee. Funding from private sources, including a generous gift from Mr. Harry Kalker (MIT '23), enabled the program to expand in the number and mix of fellows.

The Center was host during the academic year to 21 Visiting Scholars, from the US, Europe, and South Asia. Three newsletters are now being published by Center programs: The Asian Council Newsletter, Soviet Defense Notes, prepared by the Soviet Security Studies Working Group, and the Japan Program Newsletter.

MYRON WEINER

Center for Materials Research in Archaeology and Ethnology

The 1988-89 academic year was the last of three years of funding from the J. Paul Getty Trust Grant Program in support of the Center for Materials Research in Archaeology and Ethnology's (CMRAE) \$469,000 research project, *Style in Art and Technology*. All four scholars engaged in the research were resident at CMRAE during the month of May 1989 when they reported the interim results of their work in a series of seminars and planned a symposium at which they expect to share their research experience with colleagues in the fields of art history, anthropology, and archaeology. The research, a comparative analysis of the relations among art, technology, and style in Precolumbian America and Precolonial Africa, has been carried out by two teams of post doctoral investigators, each consisting of an archaeologist and an art historian: Dr. Dorothy Hosler and Dr. Thomas Cummins on the Americas team and Dr. S. Terry Childs and Dr. William Dewey on the Africa team. Drs. Hosler and Cummins conducted their field research in Ecuador, Drs. Childs and Dewey in Zaire and Zimbabwe.

Dr. Hosler joins the MIT faculty as an assistant professor of archaeology and ancient technology in July 1989, a joint appointment in the Anthropology/Archaeology Program and in CMRAE. She published three major articles in 1988-89, all on various aspects of her dissertation research concerning the technology and social construction of ancient West Mexican metallurgy. She received an NSF grant, jointly with Professor Michael Smith (Loyola), to continue her research into the early metallurgical technologies of Mesoamerica. Dr. Hosler, together with Professor Heather Lechtman (MIT, Anthropology/Archaeology Program and Materials Science and Engineering), completed a major research project which explores the nature of what may have been the first metallic primitive money system to be developed in the New World in the prehistoric era. The monograph which has resulted from this research is currently in press with *Dumbarton Oaks of Harvard University* and will appear as the next number of that institution's research series.

The Center received a \$40,000 grant from the Arthur M. Sackler Foundation, New York, to install and equip a new ceramics research laboratory, housed in Building 20 near the CMRAE Graduate Laboratory. The laboratory, under the direction of Dr. Ian Whitbread (MIT, CMRAE), is designed for state of the art ceramic petrographic analysis using computer driven image analysis systems. The laboratory's ceramic research efforts will also focus on interpreting the design and mechanical behavior of ancient ceramic artifacts using physical testing procedures in conjunction with computer simulation modelling through finite element analysis methods. Dr. Hosler joins Dr. Whitbread in the development of the physical testing-simulation modelling research on ancient ceramic materials and processes.

Dr. Michael Geselowitz joined the Center as lecturer and as supervisor of the CMRAE Graduate Laboratory. Dr. Geselowitz was one of CMRAE's first graduate students in the 1970s, having graduated from MIT with two undergraduate degrees, one in electrical engineering and another in anthropology/archaeology. Among his many responsibilities, Dr. Geselowitz expects to reconvene the monthly Materials and Anthropology seminars that the Center ran so successfully for many years. He will join Professor Lechtman in teaching the Center's graduate subject for the 1989-90 academic year: *Materials in Ancient Societies - Metals*.

HEATHER LECHTMAN

Integrated Studies Program

INTEGRATED STUDIES PROGRAM

The Integrated Studies Program (ISP) is an alternative program geared towards students who want to take their freshman science core subjects in a more intimate setting, are interested in a hands-on approach, want to know more about the place of technology in the world around them, and are, above all, eager to learn.

This year there were 21 students in the fall (11 female and 10 male with a total of six minority students) while in the spring there were 17 students (nine female and eight male with a total of five minority students); we are striving to increase our numbers for next year.

Students took two new Humanities subjects "Technologies and Cultures" in the fall, and "Technologies in Historical Perspective" on the spring. Through readings, writing and discussions the students examined how different cultures at different times dealt with similar materials and technological problems. Each subject had a workshop associated with it in which students had hands-on experience with all the technologies studied: cooking, weaving and blacksmithing in the fall, and clocks, engines and computers in the spring. Most of the units were augmented by visitors who were practicing craftsmen which gave students yet another perspective. Judging from student work and comments, they got a great deal from these subjects, though we expect that their impact will emerge much farther along in the students' careers; which is as it should be.

In their core science subjects students attended mainstream lectures while taking their recitations together in ISP with instructors who were concerned about making connections across the various fields. The Physics recitation was also augmented by a laboratory component, which is being further elaborated for next year; and we hope that we can do the same for chemistry. In the spring term we offered 8.02X Electricity and Magnetism, the experiment-based subject developed by Professor John C. King, and will also offer 8.01X Electricity and Magnetism next fall because of our conviction that students will learn science better in these experiment-based subjects.

Dr. Alan Lazarus of the Center for Space Research who teaches our physics recitations has been instrumental in the development of the laboratory oriented Physics subjects and our own laboratories. Dr. Douglas Ulmer of the Department of Mathematics continued to teach our math recitations though this was his last year, and he will be replaced by Stephen Fromm, graduate student of the Mathematics Department. Professor Kenneth C. Russell from the Department of Materials Science and Engineering taught our 3.091 Introduction to Solid-State Chemistry recitation, and Blaine McKee, graduate student in the Chemistry Department taught our 5.11 Principles of Chemical Science recitation. We are grateful for their enthusiastic participation. Christopher Craig, Technical

Instructor in ISP, developed the workshops in the Humanities subjects, and some of the Physics experiments, while also teaching the Humanities subjects. We were also fortunate to have the participation of Brian Moser, a graduate student in the Technology Policy Program, both in the development and teaching of the Humanities subjects. Marshall Hughes, ISP Senior Staff Assistant, gave invaluable support to the whole staff and students of the program. Anne Armitage, Assistant Director of ISP, kept things running smoothly both as administrator and counselor; she will be leaving the program and will be sorely missed.

Arthur Steinberg, Director

Women's Studies

CURRICULUM

Academic year 1988-1989 marked the fifth full year of operation of the Program in Women's Studies, which received this year's prestigious Irwin Sizer Award for Most Significant Improvement to MIT Education. Although more than half of the Program's full-time faculty were on leave (Professor Susan Carey, Assistant Professor Sally Deutsch, Professor Ruth Perry, Associate Professor Margery Resnick, Associate Professor Sherry Turkle), 12 subjects and two seminars were offered as part of the interdisciplinary curriculum. Three new subjects were introduced: SP433J Black Women Writers, taught by Assistant Professor Marilyn Richardson, and co-sponsored with the Writing Program, provided an important step toward a program in Ethnic Studies, and enrolled 26 students as well as a large number of auditors; SP475J Gender, Social Change and Planning, taught by Lecturer Gillian Hart, current Director of Special Programs for Urban and Regional Studies in the Department of Urban Studies and Planning (DUSP), initially drew so many students from both MIT and Boston area universities that DUSP has decided to offer this subject two consecutive semesters instead of once a year as originally planned; and SP402J Contemporary Issues in Women's Studies: Gender, Work and Politics, was taught by STS Visiting Professor Jill Conway, former President of Smith College. Professor Conway's and Lecturer Hart's subjects, which are open to both undergraduate and graduate students with permission of the instructor, opened the Program in Women's Studies to graduate students for the first time. All three subjects will be offered again next year. In addition, and in response to strong student demand, the undergraduate seminar Women and Violence, taught by Lecturer Ann Russo, will be offered henceforth as a full subject. SP431J New Women's Voices, approved as a new HASS-D subject, will explore the works of contemporary women writers from five continents beginning next semester. Finally, a new subject in the Department of Art and Architecture will be taught by Assistant Professor Leila Kinney during Spring 1990: SP474J Representations of Women in 19th Century Culture. Despite faculty attrition (this year MIT lost Professors Deutsch and Richardson), the Program continues to grow; in 1989-90, it will include 18 subjects. The variety of these offerings demonstrates the continued commitment of its faculty to broaden the Program's base outside of the humanities.

STUDENTS

This year saw the implementation of the new Women's Studies minor. Eight students have now declared Women's Studies minors, and two are pursuing a full or joint-major. Next year, the Program will initiate a luncheon seminar series on the study of gender in diverse fields, where faculty and graduate students can present their work-in-progress. Its function will be to provide an intellectual forum for all of those members of the MIT community who are pursuing gender-related scholarship.

PROGRAM AND SPECIAL EVENTS

Programming continues to be our most visible contribution to the intellectual life of the Institute, as well as the source of active collaboration with other departments. Professor Richardson's course

on Black Women Writers brought to campus two prominent Black literary critics: Deborah McDowell and Nellie McKay. The Women and Politics series, co-sponsored with the Department of Political Science and the Center for International Studies, completed its second year and sponsored seven international lecturers. Next year's guests for this series have already been scheduled. Several speakers were co-sponsored with DUSP, including Iris Berger who spoke on "Race, Gender and Trade Unions in South Africa," and Renana Jhabvala on women in India. Multiple Exposures, a highly successful film series organized by Coordinator Barbara Schulman, brought to campus five stylistically innovative films which were introduced by international speakers, critics and film-makers. In light of its continued commitment to address issues in Science and Technology, the Program sponsored a lecture on biomedical technology, as well as a series of workshops entitled Pursuing a Career in Science and Technology, which began during IAP and continued throughout the Spring semester. Finally, at the request of the Chair of the Faculty, and in order to make an educationally constructive contribution to the divisive issue of pornography, the Program organized a Registration Day alternative film screening and open discussion on the issue, which was attended by over two hundred members of the MIT community.

RESEARCH AND PUBLICATIONS

The Program's publication Women's Studies Around Boston was sent to 2000 individuals each semester, providing increased visibility and leadership for intellectual activities in this field. Women's Studies Faculty contributed actively to their individual fields, and some of these accomplishments are listed in the reports of their home departments. In the area of Women's Studies, Lecturer Robin Becker won a prestigious Creative Writing fellowship from the NEA, and her newest collection of poems was accepted by the University of Pittsburgh Press. Visiting Professor Conway garnered national acclaim for her autobiography, The Road from Coorain (Knopf), and published a co-edited volume, Learning About Women. Associate Professor Isabelle de Courtivron published an article on Clara Malraux in Biography, and another on Violette Leduc. Professor Perry published two articles on "Women in China", and became editor of Eighteenth Century Studies; Professor Resnick ran an International Symposium on Women in Spain in Madrid; her speech on Katherine Dexter McCormack will be published in Technology Review.

Effective September 1989, Professor de Courtivron will step down as Director of Women's Studies, and Professor Carey, of the Department of Brain and Cognitive Sciences, will take on that role.

SLOAN SCHOOL OF MANAGEMENT

During the 1988-89 school year the MIT Sloan School of Management continued its focus on the globalization of the world economy, the managing of technology, and the implementation of organizational change. Several new initiatives embodying these thrusts got under way.

In conjunction with the school of engineering, a new program "Leaders in Manufacturing" was begun. The program's goal is to turn out people who are masters of both the technological and management skills that are necessary to run first class production facilities. To learn what must be learned these students will spend six months working on projects that will become their masters theses at the facilities of our industrial partners -- some of the leading manufacturing firms in America.

In the same spirit, an international group of financial service firms has joined with us to create an International Financial Services Research Center that will seek to advance both the finance theories and computer technologies that are necessary to create a truly global capital market.

In all of these activities, what comes out time and time again is the need to get organizations to change and to get individuals to work together. The latter has led us to initiate a number of academic activities where students work in small teams rather than as individuals. At the beginning of the year in September, in January, and again at the end of the year in May, students have been participating in integrative exercises that will make tomorrow's managers better managers of organizational change than today's managers.

TEACHING PROGRAMS

Undergraduate Program

Over the summer of 1988 the administrative structure of our undergraduate programs was modified. The Office of Undergraduate Programs now manages the SB degree program in Management Science as well as programs serving undergraduates from other MIT departments. These latter programs include interdepartmental advising and offerings during the Independent Activities Period (IAP) in January.

The former Undergraduate Program Committee has been split into two committees with overlapping membership. The new Undergraduate Advisors Committee includes all of our Management Science program advisors (currently 15) together with our coordinators for the Undergraduate Research Opportunities Program (UROP), for the Writing Requirement, and for IAP. The Undergraduate Policy Committee comprises several of our advisors together with other faculty.

The third class in the new undergraduate program in Management Science was graduated this spring. Of the 45 graduating seniors, 16 chose an option in Information Systems, six selected Marketing Research, one chose Operations Research, and nine selected Behavioral Science. The remaining 13 students followed other specially approved options.

Seven of our graduates also received bachelor's degrees from other departments: three from the Department of Electrical Engineering and Computer Science, and one each from the Departments of Biology, Chemical Engineering, Economics, and Mathematics. Two students received simultaneously the SB degree in Management Science and the SM degree in Management.

This spring 125 students were enrolled in the Management Science Program, including six who were enrolled in Management Science as their second SB department. (Enrollment figures are based on the Registrar's fifth week counts.)

Sixty of our continuing undergraduates have declared their options as follows:

Regular Options

Marketing Research	15
Information Systems	14
Behavioral Science	8
Operations Research	2

Special Options

Finance	17
International Management	2
Legal Studies	1
Management of Technology	1

A substantial number of students from other MIT degree programs enroll in our undergraduate subjects. There were 496 such enrollments during the 1988-89 academic year, representing the classroom equivalent of 53 full-time Management Science undergraduates. Since MIT undergraduates normally take only about 60 percent of their units in their own departments, this is equivalent to having approximately 88 additional undergraduates in our program, or an equivalent total of 213.

In addition to our usual potpourri of not-for-credit offerings during the January IAP, this year we launched an intensive series of classes, readings, and exercises to introduce MIT undergraduates to the important realities of working in organizations. Designed primarily for juniors and seniors majoring in engineering and science, the series involved the coordinated participation of 12 management faculty as well as several mid-career students in our Management of Technology program. Development of this series began in the spring of 1988 through discussion with participating faculty, other management faculty, and faculty from the School of Engineering.

Enrollment for this first year was limited to just over 20 applicants. Attendance, preparation, and class participation were mandatory, in return for six units of Pass/Fail credit. Evaluations by the students and comments from participating faculty were enthusiastically positive. We plan to offer "Organizational Reality" again during the 1990 IAP.

Faculty serving as undergraduate advisors were Professors Thomas J. Allen, Ravi Bhushan, Robert M. Freund, Stephen C. Graves, John C. Henderson, Frank R. Kardes, Peter J. Kempthorne, Thomas W. Malone, James B. Orlin, and Michael A. Rappa, along with Drs. Stan N. Finkelstein and Jeffrey A. Meldman, Mr. David R. Breakstone and Ms. Hillary De Baun. Professor John D. Sterman continued as coordinator of MIT's Undergraduate Research Opportunities Program (UROP). Mr. Breakstone and Dr. JoAnne Yates were named evaluator and coordinator respectively in Management Science for Phase Two of the Writing Requirement. Dr. Meldman served as chair of the Undergraduate Advisors Committee and as IAP coordinator.

Faculty serving on the Undergraduate Policy Committee included Professors Allen, Freund, Henderson, Orlin, and ex offiis, Dr. Jeffrey A. Barks, Dr. Meldman, and Ms. De Baun. Professor Gordon M. Kaufman served as committee chair.

Dr. Meldman now serves as Director of Undergraduate Programs, and Ms. De Baun as Program Administrator.

Master's Program

The master's core curriculum was the subject of intense study as the school worked to evaluate and update course material in light of the new mission statement. Special academic projects are being planned for next year which will integrate material across course lines. A continual self-assessment is vital in such a rapidly changing world, and at the Sloan School this process assures the real-life relevance of the educational experience.

This was the inaugural year of the Leaders for Manufacturing Program, a joint effort with the School of Engineering. This specialized 24-month program awards master's degrees in both management and one of five engineering disciplines. Eleven major corporations have provided significant sponsorship for this program, which aims to prepare a select group of individuals to lead in the changing manufacturing environment.

Opportunities to learn from key figures in the world of business were numerous. The Distinguished Speakers Series brought to campus John F. Welch, Chairman and Chief Executive Officer, General Electric Company; H. Ross Perot, Founder, EDS and Perot Systems; James W. Kinnear, President, Chief Executive Officer and Chairman of the Board, Lotus Development Corporation. The highly successful Business Forums offered a presentation on Crisis Management.

The Procter and Gamble Company initiated a new scholarship for international students--the first of its kind at Sloan--and awards were received by Marcelo Larraguibel, Vito Salvaggio, and Adrian Yovanovich. Peter Genta, Sloan's nominee for the Urban Land Institute Fellowship, was a national winner. The Junior Achievers Fellowships, sponsored by the Little Family Foundation to support management education for people who developed an interest in business through the Junior Achievement program, were awarded to James Elkind, Mark Friedman, Stanley Fung, William Heflin, John Nichols, and Cyril Stevens.

Merit scholarships were awarded to second-year master's students on the basis of academic excellence and professional promise. The Miriam Sherburne Scholarship, established by the alumni/ae of the School in recognition of Miss Sherburne's more than 50 years of devoted service, was given to James W. Sawhill. This year's recipients of the Martin Trust Scholarships were David H. Bessey and Marcelo Larraguibel. These scholarships were made possible through the generosity of Mr. Trust, SM'58. The Henry Ford II Scholarship, established by the Ford Motor Company in 1978, was presented to Ruby R. Chandy. Bruce D. Temkin was the recipient of the Alexander Proudfoot - Howard J. Samuels Memorial Fellowship. This award was given by the Alexander Proudfoot Company in honor of Mr. Samuels, a former Proudfoot director and longtime friend of MIT. Scott C. Beardsley and Michael J. Houston were chosen as Henry B. du Pont III Scholars. This annual award was established by the Crestlea Foundation with a gift from the late Mr. du Pont. Jeffrey Dickson was chosen to receive the Thomas M. Hill Prize. This award, established by the late Professor Hill's friends and colleagues to honor his memory and his 30 years of distinguished service to the School, is given each year to the best student in the field of accounting.

Robert C. Brown and Dorothy K. Holmes were named the 1989-90 Seley Scholars, awards established by the late Louis E. Seley and Mrs. Seley honor graduating master's students for outstanding academic achievement, exceptional promise of business leadership, and contribution to the MIT/Sloan community. The Brooks Prize winner for the 1987-88 academic year was Philip R. O. Hampson, for his thesis entitled "Optimal Profit Sharing Rules for Petroleum Exploration and Development in Jordan," which was supervised by Professor John Parsons. Honorable mentions were awarded to Jeremy Cohen, John Krafcik, and Thomas Pounds. The Brooks Prize was established by E. Pennell Brooks, first Dean of the Sloan School, to honor the best master's thesis.

Forty-eight second-year master's students took a ten-day study tour of Japan, visiting businesses and learning about corporate and cultural life. The trip was completely planned and organized by a group of the students, and included several pre-trip lectures and classes to fully prepare the students to make the most of the experience.

The applications for admissions continue to provide a large and extremely well-qualified pool from which to make selection. We brought in an entering class of 202, including the new Leaders for Manufacturing students. The following table presents a profile of the graduating classes of 1989-90.

Profile of Graduating Master's Classes	1989	1990*
Number of Candidates	181	202
US Citizens	127	129
Foreign Citizens	54	73
Women	33	41
Members of Minority Groups	13	14
Median GMAT Score (national average is approximately 460)	650	655
Undergraduate Grade-Point Average (out of 5.0)	4.4	4.5
Undergraduate Majors		
Social Sciences and Humanities	32%	35%
Physical Sciences	12%	12%
Engineering	40%	44%
Pre-Professional	16%	9%
Average Years Full-Time Work Experience	4.0	3.0
Age at Admission:		
Under 23 years	4%	8%
23-24	33%	21%
25-26	25%	29%
27-28	14%	22%
29 and over	24%	20%

*Projected

Overall, the 1988-89 recruiting season was the best in the past six years, despite continued Wall Street shakeouts, a softening U.S. economy, and weaker than expected March-quarter results for key high tech companies. While some industries recruited and hired more actively than others, a diverse range of firms both interviewed and made offers to master's students. Any adverse business conditions appeared to affect summer hiring only.

Placement statistics for the graduating class indicate few noteworthy shifts in students' selections of permanent positions compared with 1988. As was true last year, the highest percentage of students reporting offers selected financial positions (27%). Management consulting and marketing roles were next in popularity, attracting 23% and 19% of the class, respectively.

The dominant hiring industries, paralleling 1988, were consulting, computers/electronic equipment, and investment banking. The number of students entering the manufacturing sector edged up several percentage points to 35%, compared with last year's 32%.

Greater Boston and New York City continued to attract the majority of graduates, with California a close third in terms of preferred location.

Base salaries for 1989 graduates ranged from \$36,000 - \$105,000. The class median rose to \$55,000, up 10% from 1988. The most significant shift came in the manufacturing sector, with a median increase of 8.3% recorded. Base salaries and bonuses paid by chemical and pharmaceutical firms rose more than 20%, with petroleum company figures up 6-8%.

Despite the good news overall for this year's salaries, not all industry figures moved upward. Median salaries dropped in non-banking financial services, consumer goods, and computer services.

Sign-on bonuses and other guaranteed first-year income for the Class of 1989 averaged \$11,200 with a median of \$10,000. Fifty-four percent of the students reporting salary data noted receiving a bonus as well.

In selecting final career positions, graduating students cared most about finding a job within a preferred functional area. Next in order of importance to the students were future professional advancement opportunities, the people with whom they would work, and the corporate culture. At the outset of the job search process, students also reported being strongly influenced by industry and location preferences.

Alumni/ae Relations

The alumni/ae relations program has continued to strengthen the bond between our graduates and the School, providing social, academic, and professional benefits for the graduates and a wealth of resources and important ties to the business world for the School.

A new Board of Governors was established for the national organization representing master's and doctoral program graduates. This board, made up of 15 alumni/ae from a variety of industries and countries, will provide invaluable advice and information to the School as we examine our current academic programs to ensure their relevance to the business world of today and of the next generation. Regional Sloan Clubs offered many activities, including breakfast series, and social events. Alumni/ae actively supported the School through participation in fund-raising telethons and admissions recruitment evenings.

The weekend of June 10 and 11 was reserved for reunion activities for the fifth, 10, and 25 year master's classes--seminars, softball games, and a brunch were a few of the options, with a Saturday dinner drawing a record crowd. The Ninth Annual Alumni/ae Gatherings were held in New York and Boston, with San Francisco and Washington Gatherings scheduled over the next few months.

The Society of Sloan Fellows continued to support the alumni/ae activities of the Sloan Fellows Program. Plans are underway for the 1989 Triennial Convocation. The theme has been chosen: "World Economic Conditions in the 1990s: Competition or Cooperation?". The Officers of the Society are Robert H. Campbell '78, Executive Vice President of the Sun Company (President); Richard J. Santagati '79, Chief Executive Officer of Gaston Snow & Ely Bartlett (Vice President); and Ronald L. Turner '77, President of Plessey Electronic Systems (Secretary/Treasurer).

The MIT Society of Senior Executives held its first biennial convocation on October 19-21, 1988. The theme was "Global Management Strategies in an Uncertain World," and featured speakers were French Minister of Planning Lionel Stoleru; Arthur D. Little Chief Executive Officer Charles La Mantia; and Sloan School Dean Lester Thurow. The Board of Governors includes 25 graduates of The Program for Senior Executives and meets several times a year to plan activities. John DesBarres F'84, President and Chief Executive Officer of Santa Fe Pacific Pipelines, Inc., is Chairperson; Ifigenia Boulogiane F'77, Senior Management Consultant, Arthur D. Little, Inc., is Vice Chairperson; and Bruce Levy F'87, Director, Washington Region

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C31 Systems, Grumman Data Systems, serves as Secretary. The next convocation has been scheduled for October 18-20, 1990 at MIT.

Alumni/ae relations at Sloan continue to expand. Sloan has a strong commitment to the vital relationship between graduate and School, the mutual value of which is beyond measure.

Management of Technology Program: (MOT)

The Management of Technology Program was established in 1981 at MIT and is the only program of its kind. Administered by the Sloan School of Management and the School of Engineering, this 12-month, full-time program leads to a Master of Science in the Management of Technology. It is aimed at engineers and scientists with five to ten years of work experience, and strives to prepare these professionals for more senior roles in industry and government where they will generate and manage technology-based endeavors.

This year the program was jointly managed by Tom Lee of the Department of Electrical Engineering and Computer Science and Tom Allen of the Management School acting as faculty co-chairmen. An intensive review was made over the course of the year of the program and its future direction.

The outcome of the review was a decision to expand the program to an eventual size of 55 students per year. This will require an intensified marketing effort, plans for which are in preparation. Moving from 29 students in the class of '89 to 40 in the entering class of '90 puts us well on the way towards that objective.

A second major decision involves the extension of the program to include manufacturing technology more explicitly. Students will be actively recruited from manufacturing organizations and the curriculum will be expanded to include more manufacturing-oriented courses. In this way the program will augment and complement the Leaders in Manufacturing Program which focuses on a younger, less experienced, group of students; and bring to the MOT Program additional focus on the interface between technological innovation; product design and production. This year, in addition to the regular in-class program, a one week field trip to Washington, D.C. provided informal meetings with senior government officials to explore the impact of national and international federal policy on private and public sector research. Plans are under way to introduce a second trip to either "Silicon Valley" firms or local "Route 128" firms, during either January or Spring break.

The PhD Program

During 1988-89, the Sloan School's doctoral program maintained its prominent position in the face of continuing intense competition from the other leading business schools. From our applications, we made 26 admission offers and had 15 acceptances, distributed across our 13 concentrations:

Finance	1 (1 foreign male)
Industrial Relations	3 (1 foreign female, 2 US male)
International Management	1 (1 US male)
Management of Technological Innovation	2 (US male)
Strategy & Policy	1 (foreign male)
Information Technologies (formerly MIS)	3 (1 foreign male, 1 US male, 1 US fem.)
Marketing	2 (1 foreign male, 1 US female)
Operations Research	2 (1 foreign male, 1 for. female)

While the overall percentage of US applicants rose slightly to 38%, the foreign applications declined 61% while still reflecting the large number of applications normally received from India, Korea, and several other countries within Asia. We continue to cooperate with the efforts of the American Assembly of Collegiate Schools of Business (AACSB) to recruit more qualified US applicants, and work on our own strategies for identifying prospects and sources.

The bulk of the program's graduates pursue academic careers. All ten graduates in 1988-89 class embarked on careers at Harvard, Carnegie-Mellon, and Duke.

The Doctoral Program Committee, headed by Professor James B. Orlin and coordinated by Sharon Cayley, has successfully grappled with the diverse problems of a very individualized program, including reducing the median time taken to complete the program (four and a half years) through early research ties to faculty, and a considerably enhanced financial aid package. We continue to make financial awards that are much more competitive with our principal rivals.

Alfred P. Sloan Fellows Program

On June 5, 1989, 54 Alfred P. Sloan Fellows were awarded the degree of Master of Science in Management. The Class of 1989 represented a broad diversity of backgrounds and interests, and again was drawn from organizations from the United States and abroad. The Sloan Fellows Program was the first executive education program in the United States and is now in its 58th year.

Just prior to their graduation, the Sloan Fellows completed a three-week International Management Field Trip to Europe. They visited with leading government and industrial representatives in the Soviet Union, Hungary, and West Germany.

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	<u>81-82</u>	<u>82-83</u>	<u>83-84</u>	<u>84-85</u>	<u>85-86</u>	<u>86-87</u>	<u>87-88</u>	<u>88-89</u>
<u>Industry</u>								
United States	30	28	26	30	26	31	33	25
International	15	13	15	13	12	14	12	20
<u>Government</u>								
United States	7	10	8	9	10	8	7	6
International	0	2	5	3	4	0	4	3
<u>Other</u>								
World Bank	0	0	0	0	0	0	0	0
Municipal Mgt.	0	0	0	0	1	1	0	0
Medical Mgt.	4	3	4	3	2	0	0	0
Church Mgt.	0	0	0	1	0	0	0	0
<u>University Mgt:</u>								
United States	1	1	1	1	1	1	0	0
International	0	0	0	0	0	0	0	0
	—	—	—	—	—	—	—	—
	55	55	56	57	54	55	56	54

The demand for the program continues to be strong and the quality of the nominations is extremely high. On June 16, 1989, the Class of 1989-90 arrived; there are 56 participants in the 1989-90 program.

The Director of the Sloan Fellows Program, Alan F. White is an alumnus of the program (Class of 1971). Professor Robert McKersie served as Chairman of the Faculty Program Committee.

Program for Senior Executives

The MIT Program for Senior Executives continues to attract outstanding candidates from around the world, with both 1989 sessions substantially oversubscribed. The challenges and opportunities created by an increasingly global economy received further program emphasis. Starting with the Fall 1989 program, the regular mid-program field trip to Washington was augmented to include a three day visit to Brussels, Belgium to meet with senior EEC officials and European industrialists.

The newly established MIT Society of Senior Executives, consisting of alumni/ae of the Program, held its first two-day convocation in October 1988.

In June of 1989, Professor Michael Scott Morton assumed responsibilities as Chairman of the Faculty Committee, taking over from Professor Henry Jacoby. Ms. Judy Mason became Program Coordinator upon the retirement of Ms. Sandy Anthony in August. Dr. Charles Grader continues as Director of the Program.

Greater Boston Executive Program

Continuing to serve as an important link between MIT and the Boston area community, the Greater Boston Executive Program enrolled 14 participants in the 1989 session held from January through May.

The executives met each Friday for 15 sessions on economics, finance, accounting and control, human resource management, marketing, and strategic planning offered by the Sloan faculty.

Summer Programs

During the 1989 Summer Session, School of Management faculty participated in seven Special Summer Programs.

Six of the programs were of one-week duration. The Management of Research, Development, and Technology-Based Innovation, conducted by Professor Edward B. Roberts, continued as a two-week program and once again attracted a large audience.

Two annual, intensive one-week programs were held at the MIT Endicott House and Conference Center in Dedham: The Executive Program in Financial Management, directed by Professor Stewart C. Myers; a second program in Corporate Strategy, coordinated by Professor Arnoldo C. Hax.

Four additional one-week programs were offered: Managing the Quality of Health Care was directed by Dr. Stan N. Finkelstein; System Dynamics: Microcomputer Simulation of Corporate Strategy and Social Systems was codirected by Professors John Sterman and David P. Kreutzer; Corporate Planning and Control Systems codirected by Professors Paul Healy and Dr. Morris McInnes; and Emerging New Technologies for Decision Support directed by Professor Jeremy Shapiro.

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 continued theoretical and empirical research in the areas of productivity and technical change, capacity utilization, and the response of firms' production programs to changes in input prices. He has developed measures of economic capacity utilization for multi-product firms with multiple quasi-fixed inputs.

Professor Kenneth A. Froot's research covers a broad range of theoretical and empirical topics in international economics and finance. He has studied exchange rate fluctuations and their consequences, trade liberalization, and strategies toward LDC debt.

Professor Henry D. Jacoby's primary research is on the analysis of energy and resource projects, using methods of derivative asset valuation. The focus is on the development of evaluation methods for projects facing volatile output prices and complex tax-induced non-proportionalities in cash flows.

Professor Robert S. Pindyck continued his research on irreversible investment decisions, focusing on capacity choice under price and cost uncertainty. He also studied commodity markets, testing the present value model of rational commodity pricing, and developing and testing models of commodity.

Professor Nancy L. Rose, continues her work on the determinants and effects of government regulatory policies. She has studied the effects of airline deregulation on safety, and on pricing structures and the impact of competitive and antitrust policies on consumers. She has also studied the electric utility industry, focusing on the ways in which new technologies diffuse through the industry.

Professor Julio J. Rotemberg has continued his work on the interface between macroeconomics and market structures. He has studied the ways in which imperfection in financial markets affect the government's ability to influence the economy through fiscal policy, and how various forms of price rigidity affect macroeconomic performance.

Professor Garth Saloner continued his theoretical research on standardization and compatibility. He has also continued work on the strategic consequences of vertical integration, collusive behavior, and price rigidity. In particular, he has examined the effect of import quotas on the ability of firms to implicitly collude.

Professor Richard L. Schmalensee has studied incentive regulation focusing on the parameters and performance of best linear incentive regulatory schemes when regulators can not make transfers to regulated firms and cost reduction abilities are uncertain. He has also continued his work on the analysis of consumer demand.

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.

Dean Lester C. Thurow, while continuing his position as Dean of the MIT School of Management, has continued to study US economic policy and performance. He also took part in the MIT Commission on Industrial Productivity.

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 Daniel M. Holland has continued his work on the effects of taxation and the design of tax policy.

Professor Chi-fu Huang has worked with John C. Cox on intertemporal consumption and portfolio policies (see above). In addition, he has been developing theoretical models of the Treasury Bill auction market.

Professor Andrew Lo has been on leave this year. He has done empirical research on the nature of the stochastic processes that underline security returns.

Institute Professor Franco Modigliani has continued his work on macroeconomic policy and performance. He has studied the problems of unemployment and economic stagnation in Europe, and the potential for cooperation and coordination in the design and conduct of macroeconomic policies.

Professor Stewart C. Myers has developed a signaling model to explain the role of "objective" accounting procedures to convey information about firm value to outside investors and to alleviate a tendency to underinvest which may arise for public firms under asymmetric information. In addition, he has continued his work with Richard S. Ruback (of the Harvard Business School) on capital investment hurdle rates when taxes are important and the optimal degree of financial leverage is not known.

Professor John E. Parsons has continued his work on long-term supply contracts, focusing on the international natural gas market. He has also done further work on incentive schemes, and on capital financing arrangement.

Professor David Scharfstein has been doing research at the interface of corporate finance and industrial organization. He has developed theoretical models of firm behavior and financing that focus on the role of asymmetric information.

Accounting. Professor Ravi Bhushan has worked in the area of the role of information in financial markets. He has developed a model of analyst coverage viewing the number of analysts following a firm as a proxy for the total equilibrium expenditure on information collection about the firm. He has also been developing a model of information collection that accounts for interdependence among the trading costs in various asset markets.

Professor Paul M. Healy has studied the problem of how investors interpret firms' financial policy decisions. He has written several papers on this topic. One of them examines whether firms' decisions to initiate or omit dividend payments convey information on their future earnings performance. The second examines whether stock splits convey information about the splitting firms' earnings.

Professor Patricia C. O'Brien's research has continued in two areas. The first concerns the formation of market expectations about firms' future earnings, and the second deals with shareholder voting on matters of corporate governance.

Management Science

The Management Science area encompasses the following concentrations: marketing, operations management, information technology, probability and statistics, and operations research. Several courses were introduced in the interface of Engineering and Operations Management, with a focus on manufacturing. This is the result of having hired, last year, an

outstanding group of young faculty, two of whom graduated in Mechanical Engineering from MIT.

Members from all the subgroups have played a role in the Leaders for Manufacturing Program in a wide variety of functions. For example, one of the co-directors was Professor Magnanti, who, while he is on leave next year, will be replaced by Professor Steve Graves. Professor Graves organized, with colleagues from the School of Engineering, a pro-seminar that brought together an unprecedented number of faculty from across campus. At this point, a significant number of faculty in Management Science are actively advising Leaders students in their academic work as well as their interaction with co-sponsors. Within the Sloan School, the Management Science faculty has also played an active role in the newly formed International Financial Services Research Center.

In addition to all those activities, Professor Malone is initiating a major research program on the coordination of behavioral science and technology. This new activity is likely to become a magnet for behavioral science research within Management Science. In particular, it will be synergistic with the recent initiatives of the marketing group in that domain.

Operations Management. Traditionally the group has focused on model-based analyses and studies for the design, control and improvement of operations. Contexts for this work include manufacturing operations, service operations, transportation and health care. This past year more of the focus has been on manufacturing, as the group has played the lead role for Sloan School in the Leaders for Manufacturing (LFM) Program.

Professor Bitran has continued his work on network-of-queues models, particularly as it applies in the context of manufacturing systems. He has also begun work on assessing and modeling the performance of service operations. Professor Graves' research includes the modeling of multi-echelon inventory systems, the design of assembly systems, and the development of models and methods for production planning and scheduling. New work focuses on understanding the value of production flexibility in various forms. Professor Charles Fine continues his research on the management of quality, modeling of manufacturing costs and performance, and evaluation of manufacturing technology. He has LFM projects with General Motors, DEC and Motorola, and is trying to develop models for cost of quality and new approaches for managing learning and improvement processes. Professor Lawrence Wein has developed new methods for the scheduling and control of production operations, as modeled by a network of queues. He also has discovered a method for jointly choosing due dates and the priority sequence for a multi-class single server queueing system. His work on workload-regulated input is being implemented at a French semiconductor firm, and he is involved in an industry-supported project with IBM (jointly with S. Graves) to test out and refine these methods. Professor Wein is also supervising an LFM project at Hewlett Packard.

In anticipation of the Leaders for Manufacturing Program, the group added three new faculty members, two of whom have Ph.D's in Mechanical Engineering from MIT (Eppinger and Ulrich). Professor Karl Ulrich's research includes work on design theory, modeling of manufacturing costs, and tools for design for manufacturing. He has initiated research projects with Nissan and Polaroid, and is affiliated with MIT's Artificial

Intelligence Laboratory. Professor Steven Eppinger's current research interests include design for manufacturing and real-time process control. He has begun LFM research projects with Johnson & Johnson and United Technologies, and is affiliated with MIT's Laboratory of Manufacturing and Productivity. Professor Anantaram Balakrishnan joins MIT with a Ph.D in Operations Research from Sloan 1985. His recent research includes the development of models and algorithms for network design with application to the planning of capacity expansion for local telecommunications networks. This work has been supported by both GTE and AT&T. He has begun work on system design and planning issues in manufacturing, with two particular interests, one is optimal placement and movement of objects within a manufacturing context; the second considers how to group products and processes such as deciding between a functional layout versus a cellular layout or flow line. Professor Balakrishnan is supervising the LFM project at Alcoa.

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 artificial intelligence, by examining a variety of strategic information applications, and by studying underlying organizational issues.

Professor Randall Davis continued his artificial intelligence studies of understanding and reasoning "how things work" and of the attributes of good representations of knowledge. He has also initiated new research on developing methods for cooperative knowledge acquisition. Coordination Science Technology have been the major themes of Professor Thomas Malone's research. His research has focused on three issues: (1) developing computer systems that help people work together in groups and organizations, (2) predicting and suggesting changes in human organizational structures that accompany the use of information technology, and (3) 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 intra-organizational systems (e.g., between supplier and buyer). A prototype system, called CIS/TK, which currently integrates five disparate information systems has been developed by this group. Professor John Henderson has continued to study the value of strategic information systems planning, measurement of the effectiveness of information systems' activities, and management of the design environment. Professor Chris Kemerer has developed models to aid the management of software quality, and computer-aided software engineering. Professor Wanda Orlikowski's research concerns the relationship between information technology and applied organizations. She has continued her research into the automation of systems development work, and begun a study into the role of electronic communication media in coordinating work and interaction. Dr. John Rockart continues his work on executive support, critical success factors, management of data resources, and has pursued extensive further work on 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.

Operations Research and Statistics. The operations research and statistics group focuses less on any particular managerial context than does the rest of the Management Science Area. Instead, it pursues research stressing methods of decision making and applications in a variety of problem domains.

Using statistical and probabilistic methods, Professor Arnold Barnett has studied subjects that inform public policy, particularly in the arenas of aviation safety and criminal justice. Professor Gordon Kaufman continues to focus on the exploration and exploitation of primary energy resources and on statistical and mathematical problems in resource estimation. He has also been applying his methodology to the problem of characterizing large system software failures. Professor Peter Kempthorne has examined the influence of outlier data in regression modeling in finance. He has also continued collaboration with Professor Roy Welsch on risk management in financial credit services. In addition, Professor Welsch has studied nonlinear regression for exponential family models, the use of graphics in statistical analysis, computer guided diagnostics in statistics, and new methods for variable selection in regression.

Professor Dimitris Bertsimas has worked on combinatorial optimization, probabilistic analysis of combinatorial problems, queueing theory, and queueing networks. Professor Robert Freund has continued his research on new methods of linear programming that build upon the new algorithm developed by Narendra Karmarkar at AT&T Bell Laboratories. Professor Thomas Magnanti has studied optimization models and algorithms for problems in communication system design, production management and transportation planning. This year much of Professor Magnanti's efforts focused on the start up of the LMF program. Professor James Orlin has continued his collaboration with a visitor to the Management Science Area, Professor Ravindra Ahuja of the India Institute of Technology at Kanpur. They have developed improved methods for solving several fundamental core problems in network optimization. (Some of this research was joint with Professor Robert Tarjan, who is at Princeton University.) In addition, Professor Orlin has worked on parallel computation in network optimization and on the development of modeling languages for combinatorial problems. Professor Jeremy Shapiro has continued to work on a variety of applications of mathematical programming in manufacturing, logistics planning, and financial planning.

Marketing. In 1989, Professor John D.C. Little was appointed an Institute Professor at MIT. Professor Little and the MIT Marketing Group have pioneered the use of quantitative modeling, data, and computer analysis to understand and control marketing phenomena such as advertising, promotion, couponing, channels of distribution, and new product development. Such techniques as the pretest-market, laboratory simulation of new product introductions are used throughout the packaged goods industries. The analysis of data collected by supermarket scanning of universal product codes (UPCs), a field pioneered by Professor Little, is now big business and has influence on decisions made by all levels of management.

Professor Little introduced a set of models based on artificial intelligence to analyze the tremendous volume of information available from supermarket scanners (as much as a Gigabyte per week).

Professor Glen Urban, in addition to his responsibilities as Deputy Dean for Research at the Sloan School, has expanded his pioneering work on laboratory simulation from packaged goods to durable goods. In this research with Professor Hauser, Professor Urban has developed and applied a set of models that enable automobile manufacturers to use "clinics" to forecast sales and the required marketing effort based on prototype automobiles. Professor Urban has continued this research to develop techniques (using computer-driven video disks) that "accelerate" consumers to the information states at which decisions are made.

Professor John Hauser has undertaken work on techniques to ensure that marketing, engineering, and R&D communicate effectively in the development of new products.

Professor Wujin Chu has been looking at competitive advertising from a related perspective. In work begun with a major pharmaceutical company, he has been developing data analysis techniques and mathematical models that will enable firms to be better strategic players when it comes to setting a level of advertising spending.

Professor William Qualls brings a behavioral perspective to the study of industrial marketing. He has begun investigations in this field that are likely to lead to improved insight and more effective management. Also from a behavioral research perspective, Frank Kardes and Deborah Marlinio have been involved in experiments to determine how consumers categorize and evaluate products. In particular, they have been investigating how an entirely new product such as a two-seated Buick, would be categorized by consumers.

Personnel. Several members of the Management Science group have occupied prominent positions in their respective domains, playing leading roles in their scientific societies as well as being awarded several distinctions. For example, in addition to the Institute Professorship, John Little was recognized as a pioneer in operations research by being appointed the first Morse Lecturer by the Operations Research Society of America. Professor Glen Urban received the O'dell Award from the American Marketing Association for his work in 1983 on laboratory simulation of consumer response.

Awards and Honors. Professor Magnanti was named Distinguished Lecturer in Operations Research by the Wharton School. Stuart Madnick was appointed to a Leaders for Manufacturing Professorship. Professor Bertsimas won the Nicholson Student Paper Competition sponsored by the Operations Research Society of America. Professor Freund won the 1988-89 Graduate Student Award for the Sloan School. Dr. John Rockart's recently released book, Executive Support Systems, was awarded the non-fiction "Book of the Year" prize by the Computer Press Association and has been translated into Japanese. Professor Gordon Kaufman chaired an Invited Session on Oil and Resource Conservation at the 150th Anniversary Meeting of the American Statistical Association, Washington, D.C. on August 6-10, 1988.

The following faculty received chairs during the last year: Professor Hauser, the Kirin Professor of Marketing 1989; Professor Malone, the McGovern Professorship; Professor Bitran, NTT Professor of Management

Science. Development Chairs were awarded to Professors Freund, Kemerer and Ulrich.

Behavioral and Policy Sciences

Faculty in the Behavioral and Policy Sciences Area (BPS) bring a diverse set of social and behavioral science disciplines and methodologies to bear on a broad range of managerial and public policy issues. BPS is composed of faculty groups that focus on corporate strategy, human resources and industrial relations, technology and innovation, organization studies, international management, law, communications, and system dynamics. These subgroups are not only linked together for administrative purposes, but reflect our vision of the interdependence of these functional areas for addressing the critical challenges facing managers and policy makers today.

Over the course of this past year we began exploring as a group how our research speaks to the issue of organizational change. Particular emphasis was directed to the organizational changes needed to improve the performance of individual firms and the competitiveness of our national economy. Our faculty and Ph.D. students met for a preliminary workshop at Endicott House to discuss our work on these issues and we are in the process of planning a follow-up to the work of the MIT Commission on Industrial Productivity.

Organization Studies. MIT has been a leader in the field of organizational change and development since the field was born here in the 1960s. Professor Edgar Schein continued this tradition this past year with several publications devoted to the issue of managerial education, development, and the management of planned change. We are pleased to report that Professor Schein's contributions to the field of organizational development continue to be recognized by his peers. This year he received the "1988 Organization Development Award for Excellence and Outstanding Leadership in the Field of OD" from the American Society for Training and Development.

Professor Deborah Ancona continued her various studies of how internal and external organizational factors affect the performance of new product teams and other groups. She has examined how teams in several high technology firms manage their boundaries and negotiate for resources needed to perform effectively. This work contributes to the growing recognition that teamwork and effective problem solving are critical for delivering new technologies and products to the marketplace.

Professor Robert Thomas is examining how basic choices concerning technologies are made and the political aspects of managing the development and implementation of new technology projects. He has followed three new technology projects in a major aerospace firm and concluded that the course of technology development is influenced by the dynamics of power and politics within these organizations. This year he secured a National Science Foundation grant to extend this work to other sites and has begun working with several companies in our Leaders for Manufacturing Program. His work provides new theoretical insights into how managers and workers can use the discretion available in choosing among technological alternatives to address both their own needs and those of their

organization. Professor Thomas' work in this area was recognized by his appointment as a Leaders for Manufacturing Professor.

Professor John Van Maanen is currently following up the publication of his highly acclaimed new book, Tales of the Field: On Writing Ethnography by editing a special issue of the Journal of Contemporary Ethnography that is devoted to analysis of different ways to present ethnographic research findings. In addition, Professor Van Maanen published a provocative paper on the role of emotions in organizations using observational data collected from employees at Disneyland. This work will be extended into what promises to be a fascinating book. Professor Van Maanen's stature as a leader in the field of organizational behavior and anthropology and his service to the School was recognized this year with his appointment as the Erwin H. Schell Professor of Organizational Studies.

Professor Lotte Bailyn completed her comparative study of professionals working out of their homes and offices. She concludes that professionals working at home experience high task satisfaction and place high value on intrinsic and family relations. Office professionals also experience high task satisfaction but lower personal life satisfaction and place a higher value on career and financial rewards. Professor Bailyn concludes that while homework offers potential benefits for individuals and organizations, managers will need to change their expectations and supervisory practices considerably if these mutual benefits are to be realized. Her findings from this project received considerable attention and were the subject of an article in the Economist. Professor Bailyn is carrying her work into practice as a member of several national panels and study committees and as part of the MIT Family/Work Committee.

Several BPS faculty have been actively studying individual decision-making processes and thereby building a BPS presence in the field of behavioral decision theory. Professor Donald Kleinmuntz is applying behavioral decision theory to the study of information presentation formats used in decision support systems for managers under a grant from the National Science Foundation.

Professor John Carroll published several papers on negotiator cognitions and their effects on behavior. In addition, Professor Carroll edited a book on Applied Social Psychology and Organizational Settings that explores applications of decision theories to a variety of organizational problems, how microcomputers are introduced, supported and used.

Professor John Sterman has applied system dynamics modeling techniques to the study of dynamic decision-making in managerial organizations. This year he published several papers that examine how feedback influences dynamic decision making. By integrating his system dynamics methodologies with behavioral decision theory, Sterman is forging new ground in the analysis of how managers learn and how their dynamic decisions influence the macrobehavior of firms, markets and other organizations in their environment.

Industrial Relations and Human Resource Management. MIT has a long and distinguished history as a leading source of theory and public policy analysis in the area of industrial relations and human resources. Along with colleagues in Organization Studies, faculty in this area have been at

the forefront in providing the theoretical and empirical documentation to the growing recognition of the importance of effective management of human resources to the performance of individual firms and the macro economy.

One critical set of human resource policy questions has to do with the relationships between new technology and the labor force. As part of their work for the Management in the 1990s Program, Professors Lisa Lynch and Paul Osterman published a paper that analyzes the employment effects of information technology in a large telephone company. They found that the effects of technology are not unidirectional--some jobs are lost, some of the new ones created are of lower skill and some are of higher skill.

In other work Professor Lynch has been examining the economic returns to private sector training among young workers. There is a general belief that American firms and workers underinvest in training relative to our international competitors. In this work Professor Lynch further finds that minorities and women receive proportionately less training than their male and white counterparts and benefit less from the training they receive. Professor Lynch was also honored this year with an appointment to a career development chair funded by the IRI Group.

Professor Osterman continued building on his longstanding interest in internal labor market theory by collecting and organizing a new data set that allows him to use industry level data to test alternative labor market theories. In addition, Professor Osterman directed a major study of poverty in the Boston area by conducting a large sample survey of Boston residents. This survey will provide important new data on the causes of poverty and low earnings in urban labor markets. Together with Professor Kochan,, he also published a case study of employment adjustment practices at Digital Equipment Corporation as part of Management in the 90s Program. Professor Osterman also extended the ideas contained in his recent book, Employment Futures by writing papers and a monograph for several public policy forums and audiences.

Professor Mary Rowe continued her work on the management of diversity in the labor force, a topic that will gain increasing importance and exposure in the years between now and the turn of the century. In addition to adding to her rich data base on the practice of ombudsmen offices, Professor Rowe published several papers on the role of ombudsmen, internal communications and conflict resolution, and employee development.

Professors Robert McKersie and Thomas Kochan extended their work on new models of labor-management relations by working with The Collective Bargaining Forum, a national group of corporate chief executives and union presidents. This group is now following up the publication of its first policy paper with a national forum that will explore the alternative models for the future of worker representation in the U.S. Professors McKersie and Kochan are drafting the background paper for those discussions.

Professor McKersie drafted a section of the Management in the 90s research volume devoted to implementing organizational change. In this work and in related research, Professor McKersie continues to build on and update his classic contribution on the behavioral theory of negotiations. Currently he and several colleagues are extending this research into the railroad, paper, and other industries in anticipation of preparing a new book on this

topic. Professor McKersie was also appointed to a Leaders in Manufacturing Professorship this year.

Professor Emeritus Phyllis Wallace completed her duties as this year's president of the Industrial Relations Research Association. In addition she published her book MBA's on the Fast Track that reports on the career and personal life experiences of a sample of Sloan School women and men graduates approximately five years into their careers.

Professor James Rebitzer joined the faculty at mid year and is working on theories of dual labor markets and efficiency wages. He also published a paper on the relationship between unemployment, long term employment relations and labor cost growth.

Professor Thomas Kochan completed an article on industrial relations and organizational behavior for the 1990 issue of Encyclopedia Britannica and wrote several papers for public policy conferences on the industrial relations and human resource policy issues. This year Professor Kochan was awarded a Leaders for Manufacturing Chair and was also appointed the George M. Bunker Professor of Industrial Relations.

Management of Technological Innovation. The effective management and use of science and technology are critical to the performance of contemporary organizations and the macro economies and society. Faculty in the Management of Technology subgroup are committed to discovering new concepts and methods for improving the ways new technologies enter organizations and are moved from the earliest stages of conception to productive uses in the marketplace and society.

Professor Thomas Allen continued his longstanding research on the careers of technical professionals and the performance of technical groups with support from the National Science Foundation. This year Professor Allen completed a paper that replicates and updates his important work on the career interests of engineers as they age and move up the technical and managerial ladders of their organizations.

During this past year Professor Eric von Hippel continued to study the interdependence between production tasks and the innovation process. In several published papers he extends the work in his recent book The Sources of Innovation by examining how technological information is shared among experts in different organizations.

Professor Stephan Schrader joined the faculty this year and is also exploring how technical information is shared or traded across organizational boundaries. His current work focuses on the mini-mills in the steel industry.

Professor Michael Rappa is studying how revolutionary breakthroughs in technologies occur and are absorbed (or rejected) within organizations. Professor Rappa published an initial paper on this subject and is conducting further experiments in various industrial settings to extend his data base and further test his model. An important aspect of Professor Rappa's work involves the tracing of the development and use of the professional literature on specific technologies.

Professor Edward Roberts continued his longstanding research on technical entrepreneurship and new venture management. His edited volume, Generating Technological Innovation, was published and compiled the most significant contributions to the management of technology field that were published in our Sloan Management Review over the past two decades.

Professor Marcie Tyre joined the faculty this year and is drafting articles from her dissertation on the organizational factors that influence the implementation of new process technologies. She has collected data from a large number implementation projects in several countries and finds that the speed and effectiveness of technological change is related to, among other factors, the ability of organizations to manage cross functional teams, to work with technical partners outside the organization, and to search for and absorb new information on technologies. Professor Tyre was also a very active participant in the Leaders for Manufacturing Program over the course of the year.

Professor James Utterback joined our faculty this year after serving MIT as Director of the Industrial Liaison Program. Professor Utterback is currently working to complete a book on the dynamics of innovation and is beginning several new projects on corporate transformations. Professor Utterback's expertise in technology transfer was recognized this year with an appointment as a Leaders for Manufacturing Professor.

Strategy and Policy. While most all of our research addresses issues of strategic concern to organizations, our Strategy and Policy group serves as the home for faculty who specialize in research on these issues. The group also serves as an important connecting point for others with strategic interests in a specific functional area of management.

Professor Michael Scott Morton exemplifies this type of integrating role as head of the Management in the 1990s research program for the School. The Management in the 1990s program is a five-year, \$5 million corporate-sponsored program involving a large number of our faculty. Its purpose is to study the roles played by information technologies in the strategies and processes of organizations today and in the future. During this final year of the program, Professor Scott Morton supervised the conceptualizing and drafting of the chapters for the book that will summarize the major findings and implications of this program. Professor Scott Morton's leadership and research in the information technology area were recognized this year with his appointment as the Jay W. Forrester Professor of Management.

Professor Michael Cusumano is studying the organization designs and production systems for software development in Japanese and American firms. He uses the concept of the "software factory" to describe his observations of the dominant Japanese approach, and contrasts this to the "craft" model normally used to describe software development in American firms. His analysis promises to provoke considerable thought and discussion among academics, managers and public policy representatives (such as Defense Department officials interested in software standards). A paper summarizing this work was published this year and a book manuscript has been drafted and accepted for publication by Oxford University Press.

Professor N. Venkatraman is continuing his empirical research on measurement issues in strategy research. His work represents one of the very few efforts to bring rigorous empirical research methodologies to bear on strategic management topics. A major paper on this work will be published this summer. This year Professor Venkatraman also began a long term project designed to assess the value of using information technology in organizations. IBM is funding this project.

Professor Rebecca Henderson joined our faculty this year and is studying why established firms often fail to incorporate radical or generational technical changes. She has drafted several papers from her dissertation on this subject and has designed follow-up studies in the pharmaceutical, semiconductor, and several other industries.

International Management. We have identified the challenges of managing in a global, highly competitive environment as a key dimension of our School's new mission statement. As such our International Management group plays a key role in helping to coordinate our efforts to address these issues.

Professor Donald Lessard's work this past year focused on how firms cope with exchange rate volatility as part of his broader interest in how firms respond to environmental turbulence. He has examined how "expert functions," such as the corporate finance staff, interact with line executives to frame and analyze problems and options and to implement solutions. One paper on this issue was published this year and new interviews and questionnaire data have been collected.

Professor Eleanor Westney is an organizational sociologist with special expertise and interest in Japan. This past year she extended her analysis of research and development units of American firms located in Japan. She notes that understanding the Japanese labor markets is critical to the choice of strategies for these R&D units. This work is part of her longer term efforts to study the institutionalization of different organizational forms and strategies in the subsidiaries of multinational corporations. Professor Westney's work represents another example of the conceptual linkages we are exploring between technology, human resource practices, and organizational design and change.

Professor Richard Locke is a political scientist who joined our faculty this year. His research focuses on the interactions between industrial restructuring and industrial relations in Italy. He has written several papers on this topic from his dissertation and is now in the initial stages of turning this work into a book manuscript. Professor Locke's expertise and research in Italy was recognized this year with his appointment to a career development chair funded by the IRI Group.

Law. Legal issues are growing in complexity and cost and therefore gaining increasing attention by corporate executives and public policy makers. One strategy for reducing litigation costs lies in improving our skills at negotiations and conflict resolution.

Professor Daniel Nyhart has been a leader in promoting improvements in negotiations through the development of computer-aided negotiations tools. This past year Professor Nyhart published an article on this subject and completed a major report that summarized much of his current work on this

topic for the National Institute for Dispute Resolution, the leading foundation supporting the development of alternative dispute resolution techniques. Professor Nyhart, along with colleagues Mary Rowe, Robert McKersie, and Thomas Kochan, have been helping the National Institute develop its research program and disseminate new teaching materials on this topic.

Professor Judith Lachman's research addresses another dimension of the litigation explosion by developing a life cycle of accidents which relates accident deterrence incentives to prior compensation awards and dispute settlement institutions.

Communication. Senior Lecturer JoAnne Yates published several papers in her ongoing work on the evolution of communications technologies in industry. In addition, she completed a book on this topic, Control Through Communication, published by Johns Hopkins University Press.

Tribute to a Distinguished Scholar - Jay W. Forrester: July 1, 1989 marks the formal "retirement" date of our longstanding and distinguished colleague Professor Jay W. Forrester. Professor Forrester founded the field of System Dynamics and has been the head of MIT's System Dynamics Center. This past year Professor Forrester continued drafting chapters for a forthcoming book on his national economic model. On May 23 over 200 friends and colleagues gathered to pay tribute to his many accomplishments. We were delighted to announce at that event two initiatives that will allow us to continue to honor Jay in the years ahead. Our conference room E52-552 in the BPS Area, will be refurbished and named the Jay W. Forrester Conference Room. In Addition, a Jay W. Forrester Fund has been created to support the development of innovative teaching and research tools that combine model building with traditional case study analysis. Professor Forrester has been a leading advocate of this approach to learning and teaching. We wish Jay well in all his various activities in the years ahead.

AFFIRMATIVE ACTION

The School continued its modified strategy to attract women and minorities to open positions at all ranks in the School; that is, to post positions with agencies, organizations and in placement offices where there is the greatest likelihood that qualified minorities will apply, to contact colleagues who may be in a position to identify candidates, and to raise funds to support fellowships for minority candidates, and to raise funds to support fellowships for minority candidates that apply to our degree programs.

In the area of fund raising, we were able to utilize unrestricted funds to support twelve students. The total support to minorities and women from unrestricted and restricted sources totaled \$146k, which provided support to 16 students.

We have continued to make efforts to attract women and minorities into our academic programs. This past year, our classes included the following women/minority presence: Sloan Fellows - 22% (12 of 54), Senior Executives - 6% (6 of 100), Management of Technology - 12% (5 of 40), Doctoral Program - 18% (17 of 93), Masters Program - 23% (88 of 380). We continue to

improve our outreach to qualified applicants. Two efforts by the Sloan Fellows Program are noteworthy: an appointment to Special Alumni Committee to reach out to minority candidates and two minorities to the Board of Governors of the Society of Sloan Fellows. In the Master's Program, a task force has been established to research how we can more effectively recruit minorities and women.

EXTERNAL RELATIONS

Gifts to the Sloan School in FY89 were \$6,314,692, the highest in the history of the Sloan School and up from \$4.8 million in FY88. In addition, the School received another \$3,620,552 in new pledges, to be paid out over the next five years for a total of \$9,935,244 in gifts and pledges for FY89 (\$7,168,280 in FY88), also the highest pledge/gift totals in the School's history. We received over \$1,855,000 in expendable revenue and over \$3,917,000 in endowment in FY89, up from \$1,308,336 and \$3,209,869 respectively in FY88. Systems Dynamics received \$541,886 compared to \$351,113 in FY88.

For comparative purposes, a gift by purpose analysis summarizing FY88 and FY89 cash revenues are listed below:

	<u>FY 88</u>	<u>FY89</u>
Expendable		
Chairs		
Fellowships	85,811	91,034
Research	798,360	631,400
Unrestricted	322,895	387,250*
Other	<u>101,270</u>	<u>745,496</u>
Total Expendable	\$ 1,308,336	\$ 1,855,180
Endowment		
Chairs	2,915,950	3,834,559
Fellowships	228,829	27,036
Research	-	-
Unrestricted	54,421	47,181
Other	<u>10,669</u>	<u>8,850</u>
Total Endowment	\$ 3,209,869	\$ 3,917,626
Total Expen./Endow.	4,518,205	5,772,806
Center - System Dynamics	<u>351,113</u>	<u>541,886</u>
GRAND TOTAL	<u>\$ 4,869,318</u>	<u>\$ 6,314,692</u>

*includes previously undesignated gift of Fred Kayne

Corporate cash revenues reached an all time high of \$4,773,107, almost the entire total of all cash revenue the school received in FY88. In addition another \$1,440,000 in new corporate pledges were received totaling \$6,213,107 in gifts and pledges from corporate sources in FY89. Notable among the gifts was \$1.5 million from NTT establishing the Nippon Telegraph & Telephone Professor of Management, Kirin Brewery contributed \$900,000 as first payment on a \$1.5 million pledge for a Professorship in Marketing.

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In addition, IRI (Istituto de la Reconstrucone Industriale made a significant contribution of \$650,000 as first payment on a \$1.25 million pledge for a five-year joint research and teaching program in the area of globalization of management. Other corporate gifts to note were the \$240,000 pledge from Sun Refining & Marketing Co. towards the establishment of a William Pounds Chair. We hope to increase corporate revenues in FY90 when we will have the additional assistance of the Industrial Liaison Program (ILP) in our efforts to raise funds, particularly for doctoral fellowships and chairs.

This also was a record year for Sloan designated gifts and pledges from both Institute-wide alumni and Sloan School alumni. With the help of the Institute's National Campaign Office, we received an end-of-the-year pledge from alumnus John Norris Maguire SM'60 of \$1,500,000 to fund a chair in management. Total gifts and pledges from Institute-wide alumni to the Sloan School were over \$3,210,000 in FY89 and of that total, Sloan alumni accounted for over \$2,571,000. Other significant revenue from Sloan alumni include a \$400,000 pledge from Michael M. Koerner SB'49 to establish the "Michael and Sonja Koerner Research Fund" in the areas of entrepreneurship, technology venture formation and implementation. Fred Kayne SB'60 designated \$83,619, one half of a previously undesignated gift for the Sloan School Deans Unrestricted Fund. We also received a \$25,000 pledge from Robert H. Campbell SF'78 to support the establishment of the William Pounds Chair, \$21,000 from Douglas Breeden, SB'72 for the Sloan School finance program and \$10,000 from Yoshio Yashiro, SF'88 for the Sloan School Deans Fund.

Among the significant, non-Sloan Institute alumni gifts, Richard Leghorn Ph.D.'39 established a Career Development Chair in Management of Technological Innovation with a pledge of \$750,000 of which \$500,000 was contributed in FY89.

We look forward to continued record funding for FY90 as we move into the second full year of this administration.

STAFF CHANGES, PROMOTIONS, AND VISITORS

The Sloan School is pleased to report that during the 1988-89 year, twelve faculty were appointed to distinguished chairs. John D.C. Little was appointed Institute Professor. Professor Little joined the faculty in 1962. In the field of marketing science, which he virtually created and which became his main area of work, he has performed important research in the area of optional adaptive control of marketing programs. Seven faculty were appointed to Leaders for Manufacturing Professorships, as a result of a new joint academic and research initiative between the Schools of Management and Engineering. Professorships in this program include: Professor Gabriel R. Bitran, a member of the Operations Management faculty since 1978; his research interests encompass operations in both manufacturing and service industries; Professor Stephen C. Graves, a member of the Operations Management faculty since 1977. His research has been extensive in the area of inventory management and in the control and design of production systems; Professor Thomas A. Kochan, a member of the Industrial Relations faculty since 1980. He has done research on a variety of topics related to collective bargaining in the public and private sector. Professor Stuart E. Madnick was promoted to Professor and was

appointed to a Leaders for Manufacturing chair. He joined the Management Information Systems faculty in 1972 and has performed scholarly research on the key strategic, organizational, and technology issues in the connectivity of large-scale information systems. Professor Robert B. McKersie, a member of the Industrial Relations faculty since 1980. His research interests have been in labor management relations with particular focus on bargaining activity. Robert J. Thomas, Associate Professor, part of the Organizational Studies group since 1986. His principal research focuses on organizational change and organizational design with emphasis on the process and politics of technological change. Roy E. Welsch, Professor of Statistics, on the School's faculty since 1969. His research expertise is in the area of applied statistics, data analysis techniques for management models, statistical computing, robust statistical procedures, graphical data analysis, and expert systems.

Professor John R. Hauser was appointed to the Kirin Professorship in Marketing, through a gift from the Kirin Brewery Company, Ltd. His recent research work has led to the development of a formal normative theory based upon a well grounded model of market response.

Associate Professor Thomas W. Malone was appointed to the Patrick J. McGovern Professorship of Information Systems and was promoted to Associate Professor with Tenure. The McGovern Professorship was made possible by a generous gift from Patrick J. McGovern, an alumnus from the Class of 1959. Professor Malone has been on the Sloan faculty since 1983. His interdisciplinary research has investigated the parallels between human organizations and computing systems, focusing on the structural question of how loosely coupled agents coordinate their activities.

Professor Richard L. Schmalensee was appointed to the Gordon Y. Billard Professor of Economics and Management, formerly held by Dean Lester C. Thurow. His research has focused on pricing, advertising, and other topics on the boundary between economics and marketing and has written extensively.

Professor John E. Van Maanen was appointed to the Erwin H. Schell Chair, formerly held by Professor Alvin J. Silk. Professor Van Maanen has been part of the Organizational Studies group since 1972. He has focused his research on the studies of work worlds of patrol officers in the U.S., police detectives in London, fishermen the northeastern Atlantic, and most recently, ride operators in Disneyland.

Two faculty were granted tenure this year: Associate Professor Garth Saloner joined the faculty in 1982 after receiving a Ph.D. from Stanford University. He is part of the new wave of Economists applying dynamic game theory to industrial organization and has examined the timing of price wars and other interactions between the business cycle and oligopolistic competition. Associate Professor Chi-fu Huang, joined the faculty in 1983 after completing his Ph.D. from Stanford University. His principal fields of research are financial economics and economic theory, particularly dynamic general equilibrium theory.

Paul M. Healy was promoted to Associate Professor this year. He came to the Accounting Group in 1983 after receiving a Ph.D. from the University of Rochester. His principal research fields include accounting procedure

decisions, accounting and financial markets, management compensation, corporate finance and capital markets.

New faculty appointments included Professor Paul L. Joskow, who now holds a joint appointment with the Sloan School of Management and the Department of Economics. Anant Balakrishnan, Assistant Professor of Operations Management, who earned a Ph.D. from the Sloan School in 1985; Dimitris Bertsimas, Assistant Professor of Operations Management, who also earned a Ph.D. from MIT, in Operations Research and Applied Mathematics in 1988. Steven D. Eppinger, Assistant Professor of Operations Management, received a Ph.D. from MIT in Mechanical Engineering in 1988. Rebecca Henderson, Assistant Professor of Policy and Corporate Strategy, received a Ph.D. from Harvard University in Business Economics in 1988. Andrew Lo, Associate Professor of Finance, received a Ph.D. in Economics from Harvard University in 1984. Richard M. Locke, Assistant Professor of Management and Political Science, earned a Ph.D. in Political Science in 1983 from MIT. Wanda J. Orlikowski, Assistant Professor of Management Information Systems, received a Ph.D. from New York University in 1986. James B. Rebitzer, Assistant Professor of Labor Relations, earned a Ph.D. in Economics from the University of Massachusetts. Stephan Schrader, Assistant Professor of Management of Technology, earned a Ph.D. in Business Administration from Ludwig-Maximilians-Universität München, FRG in 1988. Marcie J. Tyre, Assistant Professor of Management of Technology, received a Ph.D. from Harvard University in Production and Operations Management in 1988. Karl T. Ulrich, Assistant Professor of Operations Management, earned a Ph.D. in Mechanical Engineering from MIT in 1988.

Maurice Segall, who joined us from Zayre Corporation was appointed Senior Lecturer; Donald F. Ephlin joined the Leaders for Manufacturing Program as Senior Lecturer; Iris Mack, from the MIT Applied Mathematics Department joined us as a Lecturer.

Visiting Appointments included: Avraham Beja, Visiting Professor of Finance, from Tel Aviv University; Michael E. Bradbury, Visiting Assistant Professor of Accounting from the University of Auckland; Jeffrey L. Callen, Visiting Professor from Hebrew University; Charles A. Holloway, Visiting Professor of Operations Management from Stanford University; Jan K. Lenstra, Visiting Professor of Operations Management from Erasmus University; Wesley W. Marple, Visiting Senior Lecturer of Finance from Northeastern University; William Qualls, Visiting Associate Professor of Marketing from the University of Michigan.

Changes in academic appointments included a joint appointment in Computer Science and Engineering, and Management for Associate Professor Randall Davis; Peter P. Gil from Senior Lecturer to Director of Special Education Programs; Julian Keilson from Senior Lecturer to Adjunct Professor; Rajnish Mehra from Visiting Associate Professor to Visiting Professor in Finance; Jeffrey A. Meldman to Director of Undergraduate Programs, Senior Lecturer, and Associate Dean for Student Affairs; Franco Modigliani to Institute Professor Emeritus, Senior Lecturer; Stewart C. Myers to Gordon Y. Billard Professor of Finance and Director, International Financial Services Research Center; Donald Rosenfield to Senior Lecturer, and Project Manager for Leaders for Manufacturing; Thomas L. Magnanti became Co-Director, Leaders for Manufacturing Program.

Faculty on sabbatical leave included Professor Edward B. Roberts and Professor Stephen C. Graves.

Professor John D.C. Little was on professional leave this year. Professor Lode Li continued his leave in 1988-89. Professor Jay Forrester retired this year.

Changes in Administrative appointments included Lucinda M. Hill, to Assistant Director of the Masters Program and Director of Masters Alumni/ae Relations; Judith Mason to Coordinator, Senior Executive Program; Judith Stein to Area Administrator; Jan Austin Scott to Area Administrator; Edwin C. Nevis to Director of Executive Program Development; Linda Stantial to Director, Career Development Office; Virginia Gifford to Computer Program Coordinator.

New Administrative Staff included Emily Barrett, Assistant Director, Career Development Office; Rod Garcia, Coordinator of Masters Admissions; Diane B. Katz, Director of Masters Admission; Mary E. Marshall, Area Administrator, Economics, Finance and Accounting.

New Research Staff included Elizabeth Bayerl, Sponsored Research Administrative Staff, International Financial Services Research Center; Patricia M. McGinnis, Executive Director, International Financial Services Research Center; Nan Lux, Sponsored Research Administrative Staff, System Dynamics.

A number of individuals departed the Sloan School this year including Professor Robert C. Merton; Assistant Professors Frank Kardes, Don N. Kleinmuntz, Deborah Marlino, Patricia O'Brien, Michael E. Treacy; Visiting Professor Rajnish Mehra; Visiting Scientists Gary Perlman, Ph.D., Richard Wong, Ph.D., Ravindra Ahuja; Senior Lecturer Mel Horwitch; Lecturer Arline Golden; Research Affiliate Jon I. Martinez; Leo F. Briody, Systems Programmer; Mario L. Gnecco, Program Director, Management of Technology; Rosemary Brutico, Managing Editor, Sloan Management Review; Judith Stein, Area Administrator; Margaret Tyler, Director of Masters Admissions.

LESTER C. THUROW

SCHOOL OF SCIENCE

The education and research activities of the School of Science are centered in five academic departments and five laboratories or centers. In addition, the Experimental Study Group reports to the Dean of Science. The long range plans of the School of Science include initiatives to maintain high quality educational programs for the training of both undergraduate and graduate students and to keep the quality of research performed in the School at a high level.

EDUCATION

As part of the Institute-wide evaluation of the undergraduate education, the Deans of Science, Engineering, and Undergraduate Education jointly formed a "Working Group" in the spring of 1988 consisting of faculty members from the Schools of Science, Engineering, and Humanities and Social Sciences to consider various important issues relating to the education of MIT undergraduates in the sciences. This Working Group, under the joint leadership of Professor David Wormley of the Department of Mechanical Engineering and Professor Robert Silbey of the Department of Chemistry, met regularly for the better part of a year and made its report in January, 1989. The most significant recommendation in this report was that a biology component be added to the General Institute Science Requirements. In conjunction with this, it was recommended that the number of Science Distribution subjects required of students be reduced from three to two to keep the total number of subjects in the General Institute Requirements at a constant number. The group suggested that a pilot subject be developed (to implement the recommended biology requirement) which would combine Biology with Chemistry and Materials Science in an integrated two-term sequence. A further recommendation was that a permanent Committee on the Science Component of the General Institute Requirements be established to: (a) review on a regular basis the content and appropriateness of the Science subjects included in the General Institute Requirements; (b) assess the impact and success of the experimental pilot subject in chemistry-materials-biology in relation to its possible inclusion in the Science Core; and review the Science Distribution list of subjects to insure that each subject meets the stated objectives of the Science Distribution Requirement.

Other recommendations were to expand the laboratory requirement to include some laboratory experience for students in the first year, to develop and improve interactive learning experiences in the science core subjects, and to support the development of a new two-term physics sequence (as a component of the science core) that would include exposure to basic concepts in atomic and quantum physics.

Actions that have been taken recently to implement some of these recommendations are: (a) plans to give an experimental two-term offering in chemistry-materials-biology during the 1989-1990 school year; (b) an experimental subject in first year physics, which will include a limited laboratory component and some new material, will be offered during the fall term, 1989; and a permanent committee has been established to maintain oversight of the Institute requirements in the sciences.

STAFF CHANGES

On June 30, 1989, Professor Arthur P. Mattuck completed a five-year term as Head of the Mathematics Department and returned to full-time teaching and research in the department. Professor David J. Benney, a distinguished member of the applied mathematics group of the department, has been appointed Head, starting on July 1, 1989.

Also on June 30, Professor Maurice S. Fox stepped down as Head of the Department of Biology to return to teaching and research. His successor will be Professor Richard O. Hynes, who has been serving as Associate Head of the department.

The Science Council and the Dean will certainly miss the presence of Professors Mattuck and Fox. Both discharged their responsibilities with wisdom, competence, and style. At the same time, we welcome the new members with enthusiasm.

Professor Kim Vandiver has decided to resign from his position as Director of the Experimental Studies Group (ESG) after five years of outstanding service to this important educational program. We are fortunate to have had the service of Professor Vandiver in this program and we are equally fortunate that Professor Vernon Ingram of the Biology Department has agreed to become the new Director as of July 1, 1989. Professor Ingram has been active in undergraduate education for all of the 30 years he has been on the faculty at MIT. We welcome him to this post with pleasure and enthusiasm.

As of July 1, 1989, Professor Claude Canizares will become the Deputy Director of the Center for Space Research. Professor Canizares is a distinguished astrophysicist and a member of the faculty of the Physics Department, who has been involved in the research activities of the Center for a number of years.

AFFIRMATIVE ACTION

Affirmative action continues to be an area in the School of Science that is receiving much attention, but the results have been disappointing. During 1988, two departments succeeded in identifying prospective (underrepresented) minority faculty candidates. In the Biology Department, a Black minority candidate was targeted for a junior faculty appointment. However, after his visit to MIT it became clear that his research interests did not match those of the department, and negotiations were terminated. It should be pointed out that during the previous year the Biology Department made an offer to another Black candidate, but he decided to accept an offer in industry.

I am pleased to report that during the year the Department of Earth, Atmospheric and Planetary Sciences identified two minority candidates (one Black and one Hispanic) for possible appointments as full Professors. One (the Hispanic) will be joining the department in the fall term 1989. The department is in the final stages of negotiations with the second candidate and the feeling is optimistic that he also will agree to come to MIT.

Recent statistics on the almost unbelievably low numbers of doctoral degrees awarded to underrepresented minorities in the physical and biological sciences have correlated with our difficulties in identifying minority faculty candidates and have emphasized the importance of our efforts to increase the numbers of minority students who choose to attend graduate schools. It is only in this way that the pool size for potential faculty members can be increased. In this connection, I draw attention to the Minority Summer Science Research Program that has been sponsored jointly by the Graduate School and the School of Science. This program was generated three years ago with the purpose of stimulating qualified minority students to apply to graduate school. In the summer of 1986, during the first year of the program, eight students who had completed 2 or 3 years as undergraduates, were brought to MIT and placed in the research laboratories over a period of several weeks and at the end of the summer each student presented an oral report of his/her accomplishments in an all-day meeting attended by the Deans of Science and the Graduate School, the participating students, their mentors at MIT, and anyone else who wanted to attend. The program was expanded to include 12 students in the summer of 1987, and 16 in the summer of 1988. The program was supported by MIT funds in the first year and, since then, support has been received from agencies outside MIT (NSF and the Department of Education). The hope is to expand to 20-24 students for the summer of 1989. At present, the limitation to the number of students that can be accommodated is the amount of financial support that is available. The number of applicants for admission to the program in 1989 was more than 100. The program has obviously "caught on" and, just as obviously, has been very successful from the point of view of those at MIT who have been involved. The students have been an impressive group each year. They have been enthusiastic and very appreciative of the opportunity to spend time at a research-oriented educational institution. Three of the students from the groups on campus during the first two summers are currently enrolled as Ph.D. candidates at MIT.

Progress in the area of faculty appointments for females has been somewhat more impressive. The Biology Department appointed a new female assistant professor during 1988. The first female promotion to tenure in the Department of Earth, Atmospheric, and Planetary Sciences became effective as of July 1, 1988, and a second female faculty member in the Chemistry Department was granted tenure, effective on July 1, 1988. In addition,

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two female faculty members were promoted to tenure during the year, one in Biology and one in Earth, Atmospheric, and Planetary Sciences.

Although progress has been slow, we continue to keep the spirit of affirmative action at the forefront of the priorities for the School of Science. I believe we are moving in the right direction by emphasizing, by our actions, the need to increase the pool size of minority candidates for faculty positions.,

ACADEMIC PROGRAMS

There were 755 undergraduates in the School of Science during the past academic year, a slight decrease (-1.4%) from the previous year. The number of minority students at the undergraduate level changed as follows:

Blacks	Decreased from 16 to 15 (6% decrease)
Hispanics	Increased from 16 to 20 (25% increase)
Native Americans	None
Asian Americans	Increased from 133 to 141 (6% increase)

The female undergraduate population increased by 4.7%. Twenty-three percent of the Institute's upperclass undergraduates were enrolled in the School of Science.

Graduate enrollments in science decreased from 1,109 in the 1987-88 academic year to 1,082 (-2.4%) in the 1988-89 academic year. The total enrollment represents 23 percent of the graduate population at MIT. The number of minority students at the graduate level changed as follows:

Blacks	Decreased from 17 to 15 (12% decrease)
Hispanics	Increased from 8 to 9 (13% increase)
Native Americans	None
Asian Americans	Increased from 12 to 24 (100% increase)

The number of female graduate students decreased slightly (-1.1%).

There were 263 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'89 volume of research was approximately 90 million. This represents a 5 percent decrease over the FY'88 total of 95 million.

HONORS and AWARDS

This past year Professor Vernon Young, professor of nutritional biochemistry in the School of Science, was named a winner of the prestigious Rank Prize Fund awarded by The Rank Foundation of England.

GENE M. BROWN

Department of Biology

EDUCATIONAL ACTIVITIES

Undergraduate Program

In the past year, the maximum number of undergraduates registered as Biology majors was 284. Of these, 90 received the degree of Bachelor of Sciences in Biology: 59 in the regular Course VII Program, 22 in the VII-A Program, and nine in the VII-B Program.

The recipient of the John L. Asinari Award for outstanding research by undergraduates in Biology for 1988-1989 was Anna Kuang, a junior, working in the laboratory of Professor David Baltimore in the Department of Biology.

Ms. Elizabeth E. Quinn, a junior, received an Incentives for Excellence Scholarship Prize in August through the National Science Foundation Minority Graduate Fellowship Program.

Eight students in the Minority Summer Science Intern Program worked with Biology faculty during the summer of 1988; eight new students will work on research projects in Biology Department laboratories during the summer of 1989.

We added two new subjects to our undergraduate curriculum for the 1988-1989 year, 7.00J AIDS: Scientific Challenge and Human Challenge, and 7.041 Experimental *Drosophila* Molecular Genetics.

The Committee on the Undergraduate Program proposed this spring that a Biology requirement be added to the MIT Core Curriculum. The first pilot subject toward this goal has been developed by Professors Vernon Ingram (Biology), Robert Silbey (Chemistry), and Ronald Latanision (Materials Science and Engineering). This two semester subject, SP01 Chemistry, Materials Science and Biology, and SP02 Chemistry, Materials Science and Biology, will be taught for the first time in the 1989-1990 academic year to a trial group of 100 freshmen. The overall goal of the subject is to provide a unified and coherent progression from Chemistry to Biology. We are also reorganizing 7.01 General Biology to tailor it to the new requirement. The Biology component of SP01/SP02 or 7.01 is intended to provide the conceptual basis for all other biology subjects and will focus on cell biology, genetics and recombinant DNA techniques, embryo development and the human nervous system, and a discussion of the social context of modern molecular biology.

MIT has received a \$1 million grant from the Howard Hughes Medical Institute to strengthen undergraduate programs in the sciences in the areas of (1) student development and broadening access and (2) curriculum and laboratory development and equipment. We plan to enhance several areas of our Undergraduate Program as a result of this award. These include expansion of the Minority Summer Internship Program and support for additional UROP opportunities, the establishment of a lectureship to bring outstanding scientists to give talks specifically targeted at MIT undergraduates, and much needed support to maintain our highly innovative Project Laboratory program at a state of the art level.

Graduate Program

During the period from July 1, 1988 to June 30, 1989, 24 Ph.D. degrees and four Master's degrees were awarded in the Department; two Ph.D. and one Master's degree were awarded in the Joint Program in Biological Oceanography with the Woods Hole Oceanographic Institute (WHOI). The maximum number of Ph.D. candidates registered in the Department in 1988-1989 was 173, with another 18 in the Joint Program. The entering class in 1988, including three in the Joint Program, was 32. The class arriving in September, 1989 will be 41, including five WHOI students.

A training grant in Biotechnology, submitted jointly by the Departments of Biology, Chemistry, and Chemical Engineering, has received enthusiastic peer review. We are currently awaiting notification from NIH of the level at which the grant will be funded. We have also received a training grant in Biophysical Chemistry (jointly with Chemistry). Four training slots have been approved for the coming year. This number will increase to 8 the following year, and to twelve thereafter.

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We have expanded our graduate training in neurobiology with a new subject, 7.67J Genetic Neurobiology, and have added a new seminar, 7.76 Topics in Protein Biochemistry, to our set of special topics seminars.

RESEARCH

The research activities of the Department are in the areas of biochemistry, genetics, microbiology, cell and developmental biology, immunology, neurobiology, and virology. Individual research projects are described in the annual publication, *Biology Research Summaries*, available in the Biology Headquarters Office (56-511).

We are pleased to report that the programming for the new Biology building has been completed. The architectural firm of Goody Clancy and Associates Inc. has been selected to design the building and work is progressing.

PERSONNEL

Professors Marie Chow and Paul Matsudaira were promoted to Associate Professor effective July 1, 1989, and Professor Barbara J. Meyer was promoted to Associate Professor with tenure effective July 1, 1989.

Professors Herman N. Eisen, Irving M. London, and Annamaria Torriani retired from the faculty June 30, 1989.

Honors and Awards to the Faculty

It is a pleasure to report the following honors and awards received by various faculty members during the past year:

Professor H. Robert Horvitz was elected a Fellow of the American Association for the Advancement of Science.

Professor Richard O. Hynes was elected to the Royal Society.

Professor Vernon M. Ingram was named the John and Dorothy Wilson Professor at MIT.

Professor Arthur D Lander has been selected to be the Edward J. Poitras Assistant Professor of Human Biology and Experimental Medicine for a two year period. Dr. Lander also received one of 20 Fellowships nationwide in Science and Engineering from the David and Lucile Packard Foundation.

Professor Harvey F. Lodish received the 1989 William C. Stadie Award of the American Diabetes Association and the 1989 Piche Lecture and Award from McGill University and the Université de Montreal.

Professors Terry Orr-Weaver and David C. Page received 1989 Searle Scholar Awards for outstanding research; only 17 awards were given nationwide. Dr. Page also received an honorary Doctor of Science degree from Swarthmore College.

Professor Mary Lou Pardue was a 1989 recipient of the Wilbur Lucius Cross medal of the Yale Graduate School for her outstanding career achievements.

Professor H. Earl Ruley received the Latham Family Career Development Associate Professorship.

Professor Phillip A. Sharp received both the 1988 Louisa Gross Horwitz Prize and the 1988 Albert Lasker Basic Medical Research Award (both shared with Professor Tom Cech of the University of Colorado), and was elected an Association member of the European Molecular Biology Organization.

Professor Hermann Steller received a Pew Scholars Award.

Professor Robert Weinberg received the 1989 Lucy Wortham James Award from the Society for Surgical Oncology and the 1989 Simon B. Shubitz Award from the University of Chicago Medical School. He was also made a Fellow of the American Academy of Arts and Sciences.

**MAURICE S. FOX
RICHARD O. HYNES**

Department of Chemistry

ACTIVITIES OF THE DEPARTMENT

The Department of Chemistry, in conjunction with the Association of Alumni and Alumnae of MIT held a telethon to raise funds on November 1, 1988. The activity was a success and is planned to be repeated again in the Fall of 1989.

A Symposium honoring John S. Waugh's 60th Birthday was held on January 19 - 21, 1989 entitled "High Resolution NMR in Solids." The three day meeting stimulated the interaction between researchers in a number of disciplines, condensed matter physics, chemistry, biophysics, biochemistry and medicine who employ NMR, and other forms of magnetic resonance, to investigate specific problems and investigators who are concerned primarily with the development of magnetic resonance methodology.

A two-day symposium, co-sponsored by the Chemistry Department and the MIT Industrial Liaison Program, entitled "Biological Chemistry: Chemistry's Connection to Life" was held on February 16 and 17, 1989 in the Kresge Auditorium. The Symposium highlighted recent advances in the area of biological chemistry, including the recent research accomplishments of the MIT Department of Chemistry, industry, and other research organizations. The event brought together academic, government and industrial leaders to provide a forum for discussion of the research opportunities and mechanisms for realizing the promises of biological chemistry. Issues to be dealt with included academic-industrial relations in the area of research and the specific educational needs of industry. The program of the symposium was designed to promote participation by undergraduates, graduate students, post-docs, research staff, faculty, and distinguished representatives from the industrial community. Over 300 people attended the Symposium.

A Symposium was held on May 11 celebrating the return to MIT of Dr. Julius Rebek, Jr. to MIT as a Professor of Chemistry. Professor Kendall N. Houk from the University of California at Los Angeles, and Professor Samuel Danishefsky from Yale University were guest lecturers.

A special day-long Symposium was held on June 23 to honor Professor Irwin Oppenheim on his 60th birthday. Distinguished guests and lecturers included Professor Peter Mazur, Leiden Instituut, the Netherlands; Professor John Ross, Stanford University; Professor Adrian Parsegian, National Institutes of Health; Dr. Frank Stillinger, AT&T Laboratories; Professor N.G. Van Kampen, Institute for Theoretical Physics, Utrecht; Professor David Chandler, the University of California, at Berkeley; Professor Kurt Shuller, the University of California at San Diego, and Professor Robert Silbey from MIT. Provost John Deutch addressed the opening remarks.

Some of our graduate and undergraduate students have initiated programs to bring chemistry to local schools. Graduate students Ron Brisbois and James Nowick developed a High School Outreach Program in 1987-1988 to bring the excitement of chemical research to high schools in the Boston area. The students visit schools and present a lecture with demonstrations to illustrate the chemical research process. During the course of its first semester in the Spring 1988, Ron and James presented the program to approximately 500 students in chemistry classes at nine Boston metropolitan area high schools, and this year presented their work at the Dallas ACS Meeting and as an article in the Journal of Chemical Education. The program was also presented to the NSF Chemistry Division with NSF Director Eric Bloch in attendance. Such programs enhance the public's understanding and appreciation of chemistry.

In an effort to promote interest at an early age in hopes of stimulating stronger science programs in local elementary schools, several undergraduate chemistry majors have undertaken the development of a "Magic Show." The Magic Show was part of the Chemistry Department's Elementary Outreach Program during the Spring of 1989. The students magicians put together a "show" demonstrating how fascinating, exciting, and useful chemistry can be for 4th, 5th and 6th grade students. In addition to presenting the show, the outreach committee will also provided pre-and post-show demonstrations and activities for the teachers to do with their students. These materials are designed to prepare the students for what they will see in the Magic Show and to encourage further exploration after the show.

Professor Glenn A. Berchtold has led an important experiment in graduate education this Spring: Researchers from the pharmaceutical industry have been lecturers in a special topics graduate offering. This experiment has provided direct insight into a major segment of the chemical industry. The Department has stepped up its communication with industry by a once-a-month feature section, Chemical Sciences Industry Forum News, in our weekly newsletter, *Chemformation*.

The second year of the Women in Chemistry group continued to be highly successful. The main purposes of the group are to encourage women of the department to know and to interact with one another, to create a supportive environment where concerns can be addressed and dealt with, to spread general information on a variety of subjects dealing with life at MIT concerning both men and women, and to provide a network for women at MIT to come in contact with other women in chemistry.

A panel discussion "Ethical Dilemmas in Science...But Not Limited to Science" was sponsored by the Department of Chemistry and organized by the Women in Chemistry. Featured panelists included Dr. Mary Rowe, Special Assistant to the President and Adjunct Professor of Management; Dr. Caroline Whitbeck, Senior Lecturer in the Mechanical Engineering Department; Dr. Stephanie Bird, Research Affiliate, Brain and Cognitive Sciences Department; Dr. William E. Smith, Director of Chemical Research at Polaroid Corporation; and Professor Mark Wrighton.

PERSONNEL

Dr. Julius Rebek returned to the Department as Professor of Chemistry. Dr. Rebek earned his Ph.D. at MIT in 1970, specializing in peptide chemistry. He returns to MIT from the University of Pittsburgh, where he's been a professor in organic chemistry since 1976. Professor Rebek's variety of interests range from synthesis of biologically important molecules to the modelling of enzymatic catalysis, as well as studies of molecular recognition and mechanistic organic chemistry.

Dr. Hans-Conrad zur Loye will join the Department as Assistant Professor on July 1. Professor zur Loye earned his Ph.D. at UC Berkeley and did postdoctoral work at Northwestern University. Professor zur Loye plans to carry out investigations on solid state chemistry.

Professor Stephen Buchwald was promoted to the rank of Associate Professor, effective July 1, 1989. Professor Buchwald's research interests cover several areas of organic, organometallic, and polymer chemistry. Professor Buchwald received a 1988 Camille and Henry Dreyfus Teacher-Scholar Award and a 1988 Innovation Recognition Award from Union Carbide's Chemicals and Plastic Group.

Professor Rick Danheiser was promoted to the position of Professor of Chemistry, effective July 1, 1989. Professor Danheiser's research involves the development of new synthetic methods and strategies, and their application in the total synthesis of natural products and biologically important compounds. Professor Danheiser was also granted the Graduate Student Teaching Award in Chemistry.

Dr. Dagmar Ringe was promoted to the rank of Senior Lecturer, effective July 1, 1988. Dr. Ringe's principal responsibilities area as Director of the Undergraduate Laboratories. Dr. Ringe has led an ongoing and productive program of research in protein structure and enzyme reaction mechanisms.

Professor Stephen Lippard was named the Arthur Amos Noyes Professor on March 1, 1989, and was elected to the National Academy of Arts and Sciences on April 25, 1989. Professor Lippard also received a National Institutes of Health MERIT Award.

Professor Richard Schrock was elected a Fellow of the American Academy of Arts and Sciences on May 10, 1989.

Professor Robert J. Silbey was appointed as the Class of 42 Professor, effective March 1, 1989.

Professor John Waugh was named Institute Professor at MIT in December, 1988; was elected to the Slovenian Academy of Sciences and arts in Ljubljana, Yugoslavia in the Spring of 1989; and was awarded an honorary doctorate from Dartmouth in June, 1989.

Professor K. Barry Sharpless received the Prelog Medal from the Eidgenössische Technische Hochschule in Zürich, and the Remsen Award for 1989 from the Maryland chapter of the American Chemical Society.

Professor Alexander Klibanov was the recipient of the 1989 Ipatieff Prize, presented by the American Chemical Society.

Professor JoAnne Stubbe received a National Institutes of Health MERIT Award, and the ICI Pharmaceuticals Group 1988 Award.

Professor Klaus Biemann received the Maurice F. Hasler Award from the Spectroscopy Society of Pittsburgh on March 7, 1989.

Professor Gregory Petsko was awarded a Senior U.S. Scientist Award from the Alexander von Humboldt-Foundation in West Germany.

Numerous faculty were appointed to the editorial advisory boards of American Chemical Society publications. They include: Professor Richard R. Schrock, Accounts of Chemical Research; Professor Gregory R. Petsko, Chemical Research in Toxicology; Professor Dietmar Seyferth, Chemistry of Materials; Professor Mark S. Wrighton, Chemistry of Materials; Professor Stephen J. Lippard, Inorganic Chemistry; Professor Rick L. Danheiser, Journal of Organic Chemistry, and Professor Sylvia T. Ceyer, Journal of Physical Chemistry.

430 School of Science

Anne Lees, the Department's Personnel Administrator, left after more than 30 years of service. M.T. Kouo joined the Department as the new Personnel Administrator; she comes from the Mathematics Department where she fulfilled the same role.

IN MEMORIAM

Professor Emeritus Richard C. Lord passed away on April 29 at his home in Milton after a long illness. Professor Lord's career started at MIT in 1942 when he came to the Institute as a technical aide. He later became the Deputy Chief of the NDRC, Optics Division and in 1946 he was appointed to be the Director of the Spectroscopy Laboratory. He became a Professor of Chemistry in 1954. Dr. Lord pioneered in the use of infrared radiation for the study of molecular structure. He made widely recognized contributions to the interpretation of the infrared spectra of molecules in terms of their vibrational motion, and also to the understanding of the cohesion of molecules by means of hydrogen bonds.

NEW CHEMISTRY COURSES

Three new chemistry courses were offered in the 1988/1989 academic year.

Professor JoAnn Stubbe introduced **5.50, Bio-Organic Chemistry, Enzyme Reaction Mechanisms**. This course explored the study of the mechanisms of enzyme catalyzed reactions; analysis of transformation of substrates to products with reference to kinetics and isotope effect measurements; stereochemistry and prosthetic group reactivity; major transfer reactions, coenzyme catalyzed reactions, oxidation reactions, carbon-carbon bond forming reactions, elimination and racemization reactions.

Professors J.M. Essigmann, A.M. Klivanov, and S.R. Tannenbaum introduced **5.315, Laboratory in Protein Biochemistry** during IAP 1989. The course experiments emphasized modern methods of protein and enzyme chemistry. Principles of isolation, purification, and characterization of proteins, as well as measurement of enzymatic activity and elements of enzyme kinetics employing such techniques as gel permeation, ion-exchange and affinity chromatography, gel electrophoresis, UV/Vis spectrophotometry and HPLC.

Professors John Essigman and Robert Langer introduced a Context Course, **522J, Biotechnology and Engineering**, in the Spring of 1989. The course explored the integration of science and engineering principles with the goals of developing drugs, diagnostic agents and other products of biotechnology such as AIDS vaccines, artificial sweeteners, and cholesterol lowering drugs, and bringing these agents to the marketplace. Course topics include chemical synthesis or biosynthesis of products, safety evaluations, legal and possible ethical issues. A case-study format was utilized.

GRADUATE STUDENTS

One Master of Science degree, one joint Doctor of Science and Doctor of Philosophy degree, and thirty five Ph.D. degrees were awarded in the 1988/1989 academic year.

Many graduate students received fellowships and awards for the academic year 1988/1989. James S. Nowick, of the Danheiser Group, was selected to be the recipient of a Graduate Fellowship given by the Division of Organic Chemistry of the American Chemical Society, sponsored by Pfizer, Inc. Robert Toreki, from the Schrock Group, received a Dow Chemical Company Fellowship. Don Cha, from the Danheiser Group, was the recipient of an Arthur D. Little Fellowship. Martin Schloh from the Wrighton Group was selected by the Awards Committee of the Materials Research Society to receive a Graduate Student Award. Alexander Orsky, from the Oppenheim Group, received a departmental fellowship provided by BP America. Ronald G. Brisbois and James S. Nowick, of the Danheiser Group, were presented by Dean Gene Brown with travel awards on August 8, 1988, to be used for participation at a meeting of the American Chemical Society. These awards were given in recognition of Jame's and Ron's outstanding service to the Department in developing and successfully implementing the Chemistry Outreach Program for Boston area high schools. Nadine de Vries won a NATO Fellowship and will work in the Netherlands. Michael G. McCarthy, from the Field Group, received the department's Frank M. Greenlaw Fellowship and was selected for an AT&T Laboratories Ph.D. Scholarship.

UNDERGRADUATE STUDENTS

Twenty-six Bachelor of Science degrees in chemistry were awarded for the 1988/1989 academic year.

The 1989 MIT Award Convocation honored two undergraduates for outstanding academic and leadership qualities: Anne Louit received two William L. Stewart, Jr., awards, and Cindy Chi Wen Wang was honored by the Association of MIT Alumnae Award. Department awards were made to Dorit S. Brenner, Tom Chou, Marya Lieberman and Cindy C. Wang who were awarded the Alpha Chi Sigma Award for Achievement in Research and Scholarship and for Service to the Department. Jason J. S. Chiu, Eun-Jung

Park, and Rachel Duncan were awarded the Department's Merck Index Award for outstanding Scholarship. Lora E. Danley received the Department's Undergraduate Service Award. Tom Chou participated in the du Pont Summer Research Program, and Dorit S. Brenner received the American Institute of Chemists Foundation Student Award. Jason J. S. Chiu, Marya Lieberman and Dorit S. Brenner were invited to be members of the XI Chapter of the Phi Beta Kappa.

DISTINGUISHED VISITORS

The Chemistry Department was privileged to host four distinguished scientists in endowed lectureships during the past academic year. Professor Stephen Benkovic of Pennsylvania State was the T.Y. Shen Lecturer in October, 1988, and Professor Graham Fleming of Chicago was the Arthur D. Little Lecturer in Physical Chemistry in December, 1988; Professor Dieter Seebach from the Eidgenössische Technische Hochschule in Zürich, Switzerland was the first George H. Büchi Lecturer in Organic Chemistry in February, 1989; and Professor Jay K. Kochi, from the University of Houston, was an Arthur D. Little Lecturer in Inorganic Chemistry in April, 1989.

MARK S. WRIGHTON

Department of Earth, Atmospheric, and Planetary Sciences

FACULTY AND RESEARCH STAFF

The Head of Department changed hands on July 1, 1988, from Professor William Brace to Professor Thomas Jordan. Professor Brace elected early retirement on June 30, 1989, but he will continue to be active in many departmental matters as Professor Emeritus. Professor Brace has had a truly outstanding career at MIT; he received his PhD from the Institute in 1953 and has been a member of its faculty since 1954. Along the way, he has made a number of seminal contributions to rock mechanics, seismology, and tectonophysics, and he has collected many honors, among them the Bucher Medal, awarded last year by the American Geophysical Union, and membership in the National Academy of Sciences. His long history of leadership within the Department, administrative as well as intellectual, was capped by his distinguished seven-year term as Department Head.

Several faculty promotions became effective July 1, 1988: Kerry Emanuel and Glenn Flierl to Full Professor, Jack Wisdom to Associate Professor with tenure, and Brian Evans and Leigh Royden to untenured Associate Professor. On July 1, 1989, Royden will be promoted to tenured Associate Professor, Marcia McNutt to Full Professor, and Randolph Dole to untenured Associate Professor. A new planetary scientist, Richard Binzel, joined the department on August 1, 1988, as an Assistant Professor, and two more new faculty will begin appointments on July 1, 1989, geodynamicist Brad Hager as Professor and space-geodesist Thomas Herring as untenured Associate Professor. Hager has been named the Cecil and Ida Green Professorship of Earth Sciences, formerly held by Professor Brace, and Herring has been named to the Kerr-McGee Junior Development Chair, formerly held by Professor Royden. One faculty member, Professor David Jewitt, left the department in the summer of 1988 for the University of Hawaii, and Research Scientist Yehuda Bock accepted a position as Adjunct Professor at Scripps Institution of Oceanography in April, 1989. In September, 1988, former Senior Research Scientist Nobu Shimizu became Senior Scientist in the Department of Geology and Geophysics at Woods Hole Oceanographic Institution; he retains ties with the Department by a simultaneous appointment as Visiting Professor.

Honors

Professor Brace was presented the prestigious Bucher Medal of the American Geophysical Union. Emeritus Professor Edward Lorenz received several distinguished honors in December, 1988. He was elected a foreign member of the USSR Academy of Sciences, and received an honorary Doctor of Science degree from the University of Arizona. Also during that month he was awarded the Elliott Cresson Medal by the Committee on Science and the Arts of The Franklin Institute of Philadelphia "for his discovery, recognition, and interpretation of dynamical chaos in physical systems, and for his impact upon the scientific, mathematical and technological communities." Professor Carl Wunsch received the A.G. Huntsman Award, established by the Bedford Institute of Oceanography in Nova Scotia, which recognizes excellence of research in and outstanding contribution to the marine sciences, citing that "his application of powerful numerical analysis techniques to both historical and recent data sets has revolutionized how oceanographers look at the ocean." In 1988, Professor Marcia McNutt received an honorary Doctor of Science degree from Colorado College.

EDUCATION

The Department initiated a major effort to expand its participation in undergraduate education. A new Undergraduate Office was established, and Ms. Anita Killian, an MIT graduate, was appointed as full-time Undergraduate Coordinator. The Undergraduate Education Committee, under the vigorous leadership of Professor Jim Elliot, produced a comprehensive study of the EAPS curriculum and made recommendations for extensive changes in the course program for Department majors; these were approved by the faculty in May and will take effect during the 1990-91 academic year. Undergraduate enrollment increased to 40, up 30% from the previous year.

Our graduate enrollment for the 1988-89 academic year was 177, including 65 students in the MIT-WHOI Joint Program. The Joint Program office was relocated from Building 5 to the 9th floor of the Green Building. A new Graduate Student Advisory Committee, staffed entirely by EAPS graduate students, was set up to advise the Department Head on matters of student concern and provide a focus for Department-wide graduate activities.

GLOBAL CHANGE: A NEW INITIATIVE

Large-scale, long-term environmental changes, such as those associated with the enhanced greenhouse effect and stratospheric ozone depletion, have recently been brought to the forefront of public debate. The issues associated with these problems span the gamut of MIT interests from science and technology to national economics and international politics. The scrutiny they are now receiving is due, in large measure, to new observations and models of the atmosphere and oceans that are a mainstay of EAPS research. Recognizing the research opportunities now possible by the rapid development of new observational and modeling capabilities, the EAPS faculty, in cooperation with other groups around the Institute, have been developing initiatives for research on Global Change. An ad hoc Committee on Global Change Science, comprising 11 faculty members in EAPS and the Department of Civil Engineering under the chairmanship of Professor Ron Prinn, has completed a report entitled, *The Science of Global Change: Current Research and a Proposed Initiative*, which outlines major new MIT efforts in this exciting area. Plans for a new Laboratory for Atmospheric Chemistry are already in motion. In September, 1989, Dr. Mario Molina will join the EAPS faculty as a Professor, with a joint appointment in the Department of Chemistry; Dr. Molina is best known as the originator of the hypothesis that stratospheric ozone

is depleted by anthropogenic chloroflorocarbons, and he has recently described the detailed chemical mechanisms for the formation of the Antarctic Ozone Hole.

CURRENT RESEARCH

Geology/Geochemistry

Professors Clark Burchfiel, Kip Hodges, and Leigh Royden have completed field work in southern Tibet that demonstrates that a widespread extensional terrain developed during the past 20 million years, over the same time that the Himalaya have been shortened. The extensional features present are similar to those usually associated with regional extension; however, they paradoxically have formed within an environment of regional compression. The paradox is explained as a result of gravitational collapse of thickened crust and high topography.

In addition, Professor Hodges and students have investigated extensional processes in the North American Cordillera, showing that they account for > 50% of the denudation of the Sevier metamorphic core. Hodges and Professor John Grotzinger have been studying the relationships between the structural and sedimentological evolution of extensional basins in the southwestern United States and have found that modern Basin and Range topography is simply the most recent manifestation of extensional processes responsible for basin development since late Miocene time.

Professor Grotzinger is currently investigating the stratigraphy and evolution of an early Proterozoic foreland basin in northern Canada. This research is illustrating the effects of basin subsidence, sea level changes, and sediment supply on the geometry and style of sedimentary facies. A working model involves the assumption that higher heat production in the Precambrian influenced continental plate thicknesses.

Mars surface mineralogy continues to be one of the focal points of research by Professor Roger Burns and his students. They have suggested that iron-rich basalts extruding onto the surface conveyed high concentrations of sulfur from the martian mantle. Similar basaltic rocks were formed during the development of Earth's early crust and are associated with massive sulfide ore deposits.

Professor Fred Frey, Yan Song (MIT graduate student), and Xiachen Zhi (Chinese Visiting Scientist) determined the geochemical characteristics of Miocene basalts forming the volcanic Hannuoba Plateau, 250 km northwest of Beijing. These plateau basalts are unusual in that they include tholeiitic and alkalic basalt; the latter contains xenoliths of the subcontinental lithosphere. With geochemical data for these different types of mantle-derived samples, they have inferred the composition of the subcontinental mantle beneath northeast China, which they show has been isolated from the convecting mantle for very long time.

Professor Timothy Grove and his students have been carrying out elevated-pressure phase-equilibrium experiments to determine the temperature, depth of formation, and chemical characteristics of an enormous volume of magmas produced during the last one million years in the Cascade range of the Pacific Northwest. These studies provide information on the history of a specific volcanic arc, as well as a general framework for understanding mechanisms for material transfer from the upper mantle to the continental crust in subduction zone settings.

As an initial application of the new MIT Re-Os isotope tracer technology, Professor Stanley Hart is attempting to understand the genesis of the platinum-group ore deposits from the Bushveld layered intrusion in South Africa. The Os isotope ratios are all significantly higher than the subcrustal mantle from which the Bushveld magma is presumed to originate, but more astounding is the uniformity in the $^{187}\text{Os}/^{186}\text{Os}$ ratio (1.4-1.5) over some 150 km of outcrop length of the western Bushveld. This observation, plus the very low contents of Os in typical crustal rocks, may require fundamental changes in the accepted models of platinum-ore formation in the Bushveld Intrusion.

Professor John Southard and his students have continued their work on modeling bed configurations and stratification under oscillatory and combined flows during the rare largest storms in the shallow ocean, which leave an important imprint on the sedimentary record. They have made progress on one of the enduring mysteries in interpretation of shallow marine sedimentary rocks by finding that hummocky cross-stratification is produced by bidirectional oscillatory flow at high velocities and long periods.

Dr. Teresa Bowers has spent the past year as a visiting professor at Harvard, funded by the NSF Visiting Professorships for Women program, investigating the effects of fluid immiscibility on initiation of ore deposition. Stable isotope fractionation across the fluid miscibility gap has been numerically modeled, and the results are being applied to selected field areas to assess the physical and chemical conditions under which fluid immiscibility is important.

Geophysics

MIT now joins the ranks of other institutions prominent in the exploration of the ocean basins by having a large undersea volcano which bears its name. During an oceanographic expedition to the northwest Pacific Ocean in November and December of 1988, Professor Marcia McNutt and MIT graduate students discovered this large seamount which they believe to be more than 120 million years old, making it one of the oldest in the entire Pacific Ocean. They proposed that the heating event that led to the volcano's

formation also led to massive eruptions in the middle of the Pacific plate, analogous to those presently active in the island chains of French Polynesia.

Professor Thomas Jordan and graduate student John Goff have formulated mathematical descriptions of the complex topography on the seafloor and showed how the parameters of these models can be estimated from multibeam sonar data. Jordan and graduate student Justin Revenaugh have discovered a remarkable new set of seismic waves which allow discontinuities deep in the Earth's mantle to be imaged with a resolution not achieved by other techniques. He and graduate student Greg Beroza have developed a novel method for using the Earth's free oscillations to detect seismic events; a first application has revealed excitations that do not correspond to ordinary earthquakes and may represent low-velocity strain-release events sometimes seen as precursors to large earthquakes.

Dr. Robert King, Professor Brad Hager, and Professor Jordan, in collaboration with colleagues at several California universities, are using radio observations of the Global Positioning System (GPS) satellites to study crustal deformation in central and southern California, primarily west of the San Andreas Fault. In a series of measurements made over several years, they measured the relative positions of 20 sites with a precision of 5-15 mm and determined their relative motions to about 5 mm/yr.

Professor Daniel Rothman has continued to create, study, and apply lattice-gas models of fluid dynamics. Of continuing interest has been a new numerical model of immiscible fluids. Work during the past year has verified the model's utility in a variety of physical settings, ranging from spinodal decomposition to multiphase flow in micromodels of porous media. One new model exhibits a transition to a negative-viscosity fluid, thus opening some possibilities for lattice-gas studies of turbulence.

Research at the Earth Resources Laboratory continues to address a wide variety of topics in exploration geophysics, seismology, and tectonics. Professor Nafi Toksöz, his students and colleagues, have been developing numerical techniques for seismic wave propagation in randomly heterogeneous and anisotropic media. Analysis of data from seismic arrays and theoretical modeling are demonstrating that the Earth's crust is heterogeneous at all scale lengths, and the degree of heterogeneity is maximum at shallower depths. Dr. Arthur Cheng, in cooperation with graduate student X.M. Tang, has developed a theory for Stoneley wave propagation and attenuation in a borehole with a vertical fracture, which they can use to determine the flow properties of the fracture. The method has applications in the waste disposal, geothermal, as well as petroleum-industry areas. Dr. Robert Reilinger has been using space-geodetic observations, including the GPS technique, to study the present-day deformation of the Earth's crust in a number of tectonically active areas, including the Eastern Mediterranean region, Southern California, and the Northern Rocky Mountains.

Professor Brian Evans and his students are investigating crack healing, the brittle-plastic transition, and recrystallization and plastic flow in rocks. Recent experiments in a microscope hot stage have been particularly useful in observing pressure solution in halite. The optical technique identifies material sources and sinks in real time and allows strain rates of less than 10^{-10} /s to be resolved. The experiments should help to understand deformation of rocks in the mid- to upper-crust.

Dr. Peter Molnar, working with an overseas colleague, Dr. Philip England, has derived simple analytical approximations for the temperatures near an actively slipping thrust fault. With them, it is an easy matter to use heat flow measurements at subduction zones to place bounds on the shear stress on such faults and to examine the heat sources responsible for melting near thrust fault. They conclude that average frictional stresses approach, if they do not exceed, 100 MPa at many such faults.

The most interesting research results of Professor Theodore Madden and his students this past year are based on their magnetotelluric measurements in the several areas of California. Data from the Great Valley show the effects of two conductive lower crustal zones, one on each side of the valley, probably old, subduction-related sutures. The Basin and Range data also show strong evidence of zones in the lower crust with anomalously low resistivities, which are likely to be associated with active extension.

Planetary Science

Professor Sean Solomon and his students, in preparation for the current Magellan and upcoming Mars Observer missions, have been working with existing spacecraft data towards the goal of understanding the comparative global tectonic evolution of Venus, Mars, and the Earth. From determinations of elastic lithosphere thickness derived from altimetric and gravity data in regions of prominent topographic loads, they have estimated regional and global heat flow on Mars and Venus. Studies to date suggest that the heat lost at the few major hot spots on Mars constitutes only a small fraction of the global heat loss, while on Venus a significant fraction of the mantle heat transport may be localized to regions of pronounced upwelling. These differences can be related to different cooling histories of the mantles and cores of the two planets.

Professor Richard Binzel has performed a preliminary analysis of photometric data of the once-per-century series of mutual occultations and transits ("eclipses") between Pluto and its satellite, Charon. This analysis shows evidence for bright polar caps on Pluto and also suggests that Pluto's equatorial region may be redder than its poles. The bright regions may represent fresh methane ice, while the redder and lower albedo equator may be methane ice that has a longer exposure age to ultraviolet radiation. An interpretation that is consistent with seeing "fresh" and "old" surface material is that Pluto experiences seasons during the course of its 248-year orbit around the sun, caused by its eccentric orbit and by its rotation axis lying near the plane of its orbit.

Professor Jim Elliot, Dr. Edward Dunham, and their students have learned more about Pluto's atmosphere through analysis of their stellar occultation data obtained last summer with NASA's Kuiper Airborne Observatory. They find that Pluto has an isothermal

upper atmosphere, which overlays a haze layer that may be methane fog or a photochemical smog. They also have been preparing for an airborne expedition to observe a stellar occultation by Saturn and its rings, from which they will extend the high-resolution studies of Saturn's atmosphere and rings begun by the Voyager spacecraft.

Professor Gordon Pettengill continues his heavy involvement as Principal Investigator of the radar portion of the Magellan Radar Mapping mission to Venus, which is designed to image the surface at a resolution approaching 100 m following its arrival in the late summer of 1990. Using data from an ancillary radar altimeter on board the spacecraft, he will also supervise the preparation of global maps of the topography and surface electrical properties, using facilities at the MIT Center for Space Research. Together with Professor Solomon, Pettengill is also involved in an experiment using a laser altimeter to be placed in orbit around Mars in 1993, with the aim of producing an extremely high resolution map of its topography.

Professor Jack Wisdom is studying aspects of stability in planetary systems. He has recently identified the dynamical mechanism responsible for an instability in solar systems similar to our own which was observed in numerical experiments in the early seventies. He is carrying out a systematic numerical exploration of the outer solar system to identify regions where comet belts might be found. On a different theme, he has recently shown that two-dimensional inviscid elliptical vortices in a background shear flow are associated with large regions of chaotic advection.

Professor Charles Counselman's satellite geodesy group demonstrated an improved method of determining earth satellite orbits, using GPS signals to twelve ground stations. Professor Counselman also proposed a new satellite-based method of monitoring the Earth's crustal motion, and its atmosphere, on local and global scales. Radio signals from transmitters on the ground would be relayed by satellites to a central station where transmitter positions, satellite orbits, and atmospheric parameters would be computed. A novel combination of signal structure and processing would enable the transmitters and the satellites to be simple and small, so many points could be monitored at reasonable cost.

Oceanography

Professor Ed Boyle has mapped the phosphorus concentration of the glacial ocean 18,000 years ago; these data are important in reconstructing ocean circulation patterns and provide insight into the reasons for reduced carbon dioxide during ice ages. He and graduate student David Lea have developed the barium concentration of fossil shells as a new proxy paleochemical too. Working with postdoctoral fellow Kristin Orians, he has made the first valid titanium measurements in Atlantic and Pacific seawater and, with graduate student Rob Sherrell, the first valid trace-metal particulate measurements. He and graduate student Lex van Geen have traced the high levels of dissolved trace metals in the Mediterranean Sea to a small portion of the *Atlantic* Spanish coastline.

In collaboration with Dr. J. Meincke and other colleagues from the Federal Republic of Germany, dissolved aluminium determinations have been made by Dr. Christopher Measures on water samples collected from a variety of locations in the Greenland and Norwegian Seas. The data from these analyses will be used to constrain circulation models in this region of complex hydrography, as well as to highlight the location and mechanisms of input of materials of continental origin to the surface waters of these Arctic regions.

Professor Glenn Flierl and his students are exploring the interaction between strongly nonlinear eddies, currents, and Rossby waves. These studies reveal that the interaction between an oceanic eddy and the edge of a current such as the Gulf Stream can lead to movement of the eddy counter to the current and detachment of a patch of cyclonic fluid from the edge which pairs with the eddy and forces it to propagate away from the current. Other studies underway include the influence of surface cooling on an oceanic eddy, the flow over steep topography, and the influence of eddies and Gulf Stream meanders upon the biota.

Professor Carl Wunsch and his group have been studying global oceanic variability by satellite altimetry. These instruments make it possible for the first time to construct maps of changes in the ocean circulation on the very largest space and time scales. The major problems concern error reduction in the altimetric systems and data volume. These problems are handled by using recursive estimation methods (filtering/smoothing algorithms), Markov process representations, and oceanic dynamical models.

Professor Paola Malanotte-Rizzoli has continued her studies on the assimilation of different data types into models of the ocean circulation, together with her research associates, Drs. Roberta Young and Keith Haines. The main focus has been upon the altimetric data with different resolutions, in space and/or in time, motivated by the forthcoming launch of TOPEX. The two extreme orbit-repeat periods (10 and 20 days) have been studied, and the results show that a single satellite with either period is only moderately effective in improving the model estimates of the general circulation, although the longer periods provide better estimates of the mesoscale eddy field.

Meteorology

Professor Ronald Prinn and his colleagues have recently reported 110,000 measurements of the chemically and radiatively important trace gas nitrous oxide obtained during the Global Atmospheric Gases Experiment (GAGE) over a ten-year (July 1978-June 1988) time period which indicate a global average linear trend in N_2O of $0.30 \pm 0.08\% \text{ year}^{-1}(2\sigma)$. The measured trends and latitudinal distributions are consistent with the hypothesis that stratospheric photodissociation is the major atmospheric sink for N_2O , but not with the hypothesis that the temporal N_2O increase is caused largely by increases in anthropogenic N_2O emissions associated with

fossil fuel combustion. Instead, the primary cause for the N_2O trend appears to be agriculturally-related tropical biomass burning and resultant soil disturbance, with fossil fuel combustion playing a secondary (but still significant) role.

Professor Alan Plumb, in collaboration with colleagues at NASA and in Australia and New Zealand, has been analysing an occurrence in December, 1987, of the lowest December ozone values ever measured in southern Australia and New Zealand. They have concluded that the event was evidence of the impact of Antarctic ozone depletion on southern midlatitudes.

Professor Reginald Newell and Dr. Jane Hsiung completed a study of the annual cycle of the meridional energy flux in the Atlantic, Pacific, and Indian Oceans. The flux was found to be larger in the North Atlantic than the North Pacific at the same latitude, a difference also reflected in observed sea surface temperatures. Working with colleagues in the British Meteorological Office, they have prepared a Global Ocean Surface Temperature Atlas covering the past century, which can be used for global change studies.

Professor Richard Lindzen is studying aspects of dynamic meteorology and climatology ranging from the basic mechanism of shear instability to the reasons for the 100,000 year cycles in glaciation. Most recently, he has discovered mechanisms whereby small changes in subtropical winds can strongly influence regional weather patterns at middle and high latitudes. He has also explained why satellite radiance data seems to have no positive impact on northern hemisphere weather forecasting.

Professor Peter Stone used both theoretical and numerical models to calculate the effect of condensation on the vertical fluxes of heat and moisture due to baroclinic eddies in the atmosphere. He found that the fluxes were more than doubled by the condensation. This suggests that the large-scale, baroclinic eddies play a much more important role in setting the vertical temperature structure of the mid-latitude atmosphere than was apparent previously.

Professor Randall Dole has identified how synoptic-scale eddy activity varies for several widely differing large-scale flows, and has also examined how the changes in eddy activity influence the large-scale flow anomalies. The results indicate that interactions between the eddies and the large-scale flow often play a significant role in both the development and maintenance of the large-scale flow anomalies.

Professor Kerry Emanuel spent part of his sabbatical writing a graduate-level text on atmospheric convection, and the rest of it taking measurements from a research aircraft as part of an experiment designed to understand maritime cyclones in winter. In addition, he has continued research into the dynamics of tropical cyclones, cumulus convection, and other tropical circulations.

Dr. Bruce Fegley has continued experimental measurements of the gas-solid reactions forming $CaSO_4$ under Venus surface conditions. These results show that this process is independent of the CO_2 and O_2 partial pressures and is proportional to the SO_2 partial pressure in the Venus atmosphere. The first experimental measurements on the reaction of SO_2 with diopside and wollastonite have also been made, and show that Ca-silicates are also a SO_2 sink on Venus.

Professor Earle Williams and his colleagues in the Weather Radar Laboratory are engaged in studies of the electrical activity of deep convection in the vicinity of Darwin, Australia, where order-of-magnitude differences in the lightning rates of continental and maritime thunderstorms have been observed. Collaborative studies with the Darwin Meteorological Bureau on the day-to-day variation in the strength of the Hadley cell over the Maritime Continent suggest that the strongest circulation is not associated with the electrically spectacular continental "hot towers" but rather with the more widespread, more persistent, and less vertically developed monsoonal convection.

THOMAS H. JORDAN

Department of Mathematics

DEPARTMENTAL STATISTICS

Students

During the academic year 1988-89, there were 193 undergraduates majoring in mathematics, including 54 in the 18C program (Mathematics with Computer Science). The figures for the senior class were: 62 graduating seniors, including 15 in 18C, and 9 double majors.

There were this year a total of 135 graduate students in mathematics, all in the Ph.D. program. This year 34 students received their Ph.D., including 25 this June -- a record number.

Faculty

There were 55 faculty members in the Mathematics Department, 21 in the Applied Mathematics Group, and 34 in the Pure Group. This included the following on whole or partial leave:

Prof. Richard Dudley (Spring)
Prof. Victor Guillemin (Fall - partial)
Prof. Kenneth Hoffman (Year - partial)
Prof. Daniel Kan (Spring)
Prof. George Lusztig (Fall - partial)
Prof. James Munkres (Spring)
Prof. Gian-Carlo Rota (Spring)
Prof. Gerald Sacks (Year)
Prof. Harold Stark (Spring)
Prof. Gilbert Strang (Spring)
Prof. Michele Vergne (Year)
Asst. Prof. Luis Casian (Year)
Asst. Prof. Ehud Hrushovski (Spring)
Asst. Prof. Stephane Zaleski (Year)

Among the visitors for a substantial portion of the year were:

Stella Ashford (Year, Assoc. Prof., Southern University)
Enrico Arbarello (Fall, Prof., University of Rome)
Alexander Beilinson (Fall, Prof., Landau Institute, Moscow)

FACULTY CHANGES

Retirements and Resignations

Prof. Irving Segal retired this year after almost 30 years of service at M.I.T., and a distinguished career in analysis and mathematical physics. He will continue his research program on campus.

438 School of Science

Prof. Michele Vergne resigned after an extended leave to permanently remain at the Ecole Normale Superieure in Paris.

Four Assistant Professors resigned: Luis Casian will go to Ohio State University, David Shmoys will go to Cornell, Stephane Zaleski to the University of Paris, and C. Fred Pearson to M.I.T.'s Lincoln Laboratory.

New Appointment

Alexander Beilinson of the Landau Institute (Moscow) has accepted a position as Professor. He will divide his time between M.I.T. and Moscow for the next few years. His fields are algebraic geometry, number theory, Lie theory, and theoretical physics.

Michael Hopkins has accepted a position as Associate Professor; his field is algebraic geometry.

Ezra Getzler has accepted a position as Assistant Professor; his field is analysis.

Steven Strogatz has accepted a position as Asst. Prof. of Applied Mathematics; he works in a variety of fields having as a unifying theme the modeling of continuous physical phenomena by differential equations.

Mauricio Karchmer has accepted a position as Asst. Prof. of Applied Mathematics.; his field is theoretical computer science.

Promotions

Michael Sipser and F. Thomson Leighton have been promoted to Professorships.

Baruch Awerbuch and David Shmoys (leaving) have been promoted to Associate Professorships without tenure.

Honors, Prizes and Awards

Prof. Sigurdur Helgason received the doctorate honoris causa from the University of Copenhagen in November. The citation cites his influential work in differential geometry, Lie groups, and harmonic analysis on symmetric spaces, as well as his great influence on Danish mathematics through his visits and his advising of Danish students in the United States.

Prof. Isadore Singer received an honorary doctorate from the University of Michigan this May, for his work in analysis and differential geometry, as well as his influential role in national science policy.

Two Steele prizes to M.I.T. Mathematics faculty were awarded at the American Mathematical Society Centennial meeting last summer:

Prof. Sigurdur Helgason received the prize for his three books on differential geometry and harmonic analysis on symmetric spaces and Lie groups;

Prof. Gian-Carlo Rota received the prize for his 1964 paper on the theory of Moebius functions, cited for revolutionizing the field of combinatorics by the introduction of new algebraic techniques which systematized a group of seemingly disparate methods.

Prof. Isadore Singer received the Wigner Prize for his work in the foundations of mathematical physics.

Prof. Arthur Mattuck shared the School of Science teaching prize with Prof. Anthony French of physics.

Assoc. Prof. Michael Sipser received the Graduate Students' Council teaching award.

Asst. Prof. Ehud Hrushovski received a five-year Presidential Young Investigator award from the N.S.F. for his work in logic.

Assoc. Prof. David Anick received a two-year Sloan Foundation grant for his work in algebraic topology.

Two graduate students, Shi-rong Lu and Dorshka Wylie, received Alfred P. Sloan Doctoral Dissertation Fellowships for their thesis work.

Two mathematics seniors, David Blackston and David Williamson, both in the 18C program, shared the Jon A. Bucsela Prize in Mathematics for distinguished scholastic achievement, professional promise, and enthusiasm for mathematics.

Administration

Prof. Arthur Mattuck is completing the last year of his five-year term as Department Head. He will be succeeded by Prof. David Benney, who has accepted a five-year appointment by the Dean of the School of Science, Gene Brown.

To aid in the transition, the current Committee Chairmen will be continuing through the next year:

Richard Melrose -- Pure Committee
Daniel Kleitman -- Applied Committee
David Jerison -- Undergraduate Committee
Sigurdur Helgason -- Graduate Committee
James Munkres -- Committee of Advisors

Prof. Kenneth Hoffman has accepted a new position in Washington as Executive Officer of the Board on Mathematical Education of the NAS - NRC. He will continue on partial leave from M.I.T..

Educational

Of the variety of educational work going on in the department, we single out two directions as potentially significant for the M.I.T. core undergraduate education.

There is experimentation in various directions with the calculus program. Prof. Gilbert Strang is writing a textbook and offered for the first time this year a version 18.01A designed for the group of entering students with no previous calculus experience. At the same time, Profs. Greenspan and Benney presented their version of calculus, which stresses modeling and adds several non-traditional topics, to the large group of entering students with a year of high-school calculus, but no formal advanced placement.

In another direction, there are plans next year to experiment with regularly scheduled guided study-group/tutorial sessions for those students in the regular 18.01 who are identified early as being in trouble. These students will be required to limit their load before being allowed to register for these supplementary seminars.

Project Athena has been used successfully for several years in differential equations. The menu-driven program, however, has been rather inflexible, and adapting it to the successive changes in Athena's operating system has been a major headache and expense. With the stabilization of the Athena environment, work has proceeded on a more flexible system (LAS - the Lecture Authoring System) which will be able to accommodate calculus as well. We hope to be able to try this out in calculus problem sets next fall. The work has been done by undergraduates, under the joint direction of Jon Haass in Mathematics and Ed Moriarty in EECS.

Department of Physics

In spite of financial stringencies during the past year, all major research programs in the Department have remained active and some important new initiatives have been started, as described in the detailed accounts later in this report. The Department has continued to address the challenge it faces as a major component of the MIT educational program.

The members of the Physics Department continue to provide leadership for the major MIT interdepartmental laboratories. At present the Directors of the Laboratory for Nuclear Science (LNS), Bates Linear Accelerator (BLA), National Magnet Laboratory (NML) and Spectroscopy Laboratory are members of the Physics Department, as well as the Associate Director of the Research Laboratory of Electronics.

In 1988-89 the total number of the Faculty was 86. The following members of the Faculty received promotions: to Associate Professor without Tenure, Robert Ledoux and Jean-Pierre Revol. One new Professor with Tenure joined our Faculty: Paul Schechter; one new Assistant Professor also joined: Richard Milner. One member of the Faculty retired: Peter Demos; one member of the Academic Staff retired: Jan Orsula. Two Assistant Professors resigned: Susan Cooper and B. Gabriel Kotliar.

Faculty on leaves or sabbaticals during the year included Professors Ulrich Becker, Eric Cosman, Ronald Davidson, Peter Demos, Edward Farhi, Jerome Friedman, Lee Grodzins, K. Uno Ingard, Vera Kistiakowsky, Patrick Lee, June Matthews, Robert Redwine, Jean-Pierre Revol, and Rainer Weiss. Faculty Sloan Fellows included Professors Edmund Bertschinger, Mehran Kardar, B. Gabriel Kotliar, Aneesh Manohar, Janos Polonyi, and John Tonry.

A number of our faculty received awards during the past year. Professors Mehran Kardar, Aneesh Manohar, Richard Milner, Janos Polonyi, and John Tonry received Presidential Young Investigator Awards. Professors Michael S. Feld and Felix M. H. Villars were elected Fellows of the American Association for the Advancement of Science. Professor Walter H. G. Lewin received the 1988 Buechner Faculty Teaching Prize. The American Physical Society awarded the 1989 W. K. H. Panofsky Prize jointly to Professors Jerome I. Friedman and Henry W. Kendall. Professors Katherine Freese and John M. Graybeal received Sloan Research Fellowships from the Alfred P. Sloan Foundation. Institute Professor Emeritus Victor F. Weisskopf won the 1988 Enrico Fermi Award given by the Department of Energy. The American Association of Physics Teachers named Professor Anthony P. French winner of the 1989 Oersted Medal and Professor Robert J. Birgeneau the 1989 Richtmyer Lecturer. Professor Samuel C. C. Ting was elected as a foreign member of the USSR Academy of Sciences. Professor A. Nihat Berker was presented the Tubitak Science Award, Turkey's highest scientific honor. The 1988 European Biancamano Prize for Scientific Research was awarded to Professor Bruno Coppi. Professor Anthony French was a co-recipient of the School of Science Teaching Prize. Professor Barton Zwiebach received the 1989 Graduate Student Council Teaching Award for Physics. Professor Alan Guth was elected to the National Academy of Sciences. Professor A. Nihat Berker was elected a Fellow of the American Physical Society.

With regard to student honors, the 1989 Buechner Student Teaching Prizes were awarded to James F. Abbott and Phillip Podsiadlowski. Jason Crain received the 1988 Joel Orloff UROP Award. Robert Newman received the Laya and Jerome B. Wiesner Award. Eric M. Reifschneider was presented with the Malcolm G. Kispert Award. Marcos G. Fernandes was presented with the Straight Award. James F. Abbott received the Avery Ashdown Prize. Ten students were elected to Phi Beta Kappa: Mark V. Andersen, Leon M. Balents, Nicholas P. T. Bateman, Christopher D. Carone, Steven M. Crooks, Julianne Dalcantan, Kenneth M. Dinndorf, Ronald R. Marquardt, Eric M. Reifschneider, and Catherine S. Trotter.

Educational Achievements

The Department has continued to maintain a relatively constant number of graduate and undergraduate students, as well as a relatively constant number of credit units per faculty member. This year, the number of undergraduate majors was 230, and the number of graduate students was 300. The number of degrees awarded totaled 77 S. B., 8 S. M., and 39 Ph. D.

CURRENT RESEARCH

Astrophysics Division

Research in the Astrophysics Division deals with phenomena ranging from the earth's magnetosphere to the most distant quasars. Observational programs involve the collection, analysis and interpretation of data from a wide variety of ground-based and space-based observatories. There are major efforts for the development of new instrumentation to detect cosmic radiation across the electromagnetic spectrum, from radio to gamma rays. Theoretical research is carried out on topics ranging from plasma physics in the solar system, through stellar evolution, to the large-scale structure of the universe.

1. High Energy Astrophysics

Observational programs in X-ray astronomy rely on the extensive data archives from previous space missions and on collaborative programs involving Japanese and European satellites. In galactic astrophysics, researchers are investigating several phenomena involving neutron stars in binary star systems, particularly X-ray bursts and quasi-periodic oscillations. These are related to properties of the neutron star, its intense magnetic field, and the process of accretion. Study of the eclipses of the X-ray star by the companion also gives information about the structure of companion's stellar atmosphere. There are also continuing efforts to discover and identify previously unknown X-ray sources. High resolution X-ray spectroscopy of supernova remnants is used to perform plasma diagnostics of the interstellar material and stellar ejecta which were shock heated by the supernova explosion. Once the plasma properties are understood, it is possible to deduce the chemical composition of the material. Similar studies also apply to gas in clusters of galaxies, where they reveal the presence of large-scale cooling flows involving up to several hundred solar masses per year. Other extragalactic studies include the identification of new X-ray quasars and active galaxies and measurements of the X-ray spectral properties of quasars at high redshift. Several major instrumentation projects are underway including design and definition of instruments for the Japanese Astro-D mission, the X-ray Timing Explorer, the Advanced X-ray Astrophysics Facility, the Explosive Transient Camera, and the High Energy Transient Experiment.

2. Radio Astronomy

A central area of research has been the identification and study of candidate gravitational lens systems. The Very Large Array of the National Radio Astronomy Observatory is used to map the radio structure of objects initially identified in the extensive MIT-Greenbank radio survey of the sky. Maps showing the double or multiple structure characteristic of objects whose images are affected by the gravity of a foreground galaxy or cluster (the gravitational lens) are listed as candidates. Follow-up optical observations are then performed to confirm the identifications. To date several strong lens systems have been found, including the first evidence of an "Einstein ring." Other activities in radio astronomy include further development of space antennas for Very Long Baseline Interferometry.

3. Optical Astronomy

The main MIT facility for optical astronomy is the Michigan-Dartmouth-MIT observatory in Arizona, which has a 1.3m and a 2.4m telescope with modern instrumentation. Researchers also make regular use of the telescopes of the National Optical Astronomy Observatory in Arizona and Chile, telescopes in Hawaii, Las Campanas and Mount Palomar. Observational programs are carried out by many of the groups in the Astrophysics Division. There are active programs for the identification and study of X-ray sources and of gravitation lens candidates from radio surveys. Detailed studies are carried out of galactic X-ray sources, such as the putative black hole A0600-00, cooling flow clusters, and high redshift clusters of galaxies. There is a major program for determining the Hubble constant by a novel technique that involves measurements of the statistical fluctuations in the surface brightnesses of elliptical galaxies. A continuing program of observational studies of galaxies will help trace the large-scale structure of the universe. Closer to home, observations of carbon stars in the Milky Way are being made to trace the amount and distribution of dark matter in the Galactic sky.

4. Gravitational Radiation

Members of the Astrophysics Division are part of a collaboration with investigators at CalTech for the development and construction of a Laser Interferometer Gravitational Wave Observatory (LIGO). Development of a prototype antenna continues as does the design and planning of the full-scale interferometer. Primary issues involve laser power and stability, isolation and noise sources, optimal data logging and analysis algorithms and large-scale high vacuum technology, together with understanding of the sources of background noise and possible sources and levels of astronomical gravitational waves.

5. Observational Cosmology

The Cosmic Background Explorer (COBE) group is preparing for the launch of the spacecraft in late 1989. The group's primary focus is the Far Infrared Absolute Spectrometer (FIRAS) which will make precise measurements of the spectral shape of the cosmic microwave background. A major question is the reality of deviations from an ideal black body spectrum recently found by Japanese and U S investigators. If confirmed, this excess emission suggests significant radiation by dust and/or an episode of significant reheating in the early evolution of the universe. A balloon payload designed for measuring small-scale anisotropies in the Cosmic Background Radiation is being prepared for reflight following the balloon failure this fall. The instrument achieves an order of magnitude improvement in sensitivity over previous detectors in the sub-millimeter range.

6. Space Plasma Physics

The space plasma group continued to interpret data from the Voyager spacecraft during its passage through the magnetospheres of Jupiter, Saturn, and Uranus and through interplanetary space. Preparations are also being made for the encounter of Voyager II with Neptune, which will occur in August 1989. The studies reveal the properties of each planet's magnetosphere and also address fundamental questions in plasma physics. Temporal and spatial variations in plasma properties reflect changes in the solar wind and, for example in the case of Jupiter, changes in local sources of plasma. The group is also developing a plasma experiment for the WIND spacecraft, which is one of several that will form the international Global Geoscience Program.

7. Theoretical Astrophysics

Studies have been made of the large-scale structure of the universe and departures from the smooth Hubble velocity flow in the context of a universe dominated by cold dark matter. These involve both N-body simulations and statistical analyses of existing data on galaxy distances and large-scale streaming motions. The possible role of cosmic strings on early galaxy formation has also been investigated, as have limits on possible candidate dark matter particles. Further developments in the theory of the inflationary universe have permitted consideration of the possibility of creating a new inflationary episode in the present universe (i.e. creating a universe in the laboratory). Calculations show that such a "child" universe would quickly decouple from this one and therefore would not be disruptive. In a related area, theoretical investigations have considered the formation of dendritic structures in the domain boundaries during the phase transition in the early universe. Also calculations were made of the possible observable effects of magnetic monopoles in main sequence stars in order to set tighter limits on the density of monopoles in the universe. In more conventional stellar evolution, a new theory has been developed to explain the sudden increases in luminosity observed in certain protostars as the breakout of a luminosity wave due to a sudden change in the heat capacity of the outer envelope of the star. Other work on protostars involves numerical computations of accretion phenomena. In addition to single stars, evolutionary effects have been considered in low-mass binary systems, such as those that eventually give rise to some X-ray binaries or to binary pulsars.

Atomic, Plasma, and Condensed Matter Physics Division

1. Atomic, Molecular, and Laser Physics

There has been a resurgence of interest in classical dynamics stimulated by a growing appreciation for the role of non linear phenomena and the development of new techniques for handling non linear problems. The onset of disorderly motion-chaos is of particular interest. The manifestation of chaos in quantum mechanical systems is of fundamental concern in this area. Classical motion is recognized to be a special case of quantum behavior, but quantum mechanics does not appear to have much in common with disorderly motion. Although many numerical experiments have been carried out, experimental evidence is lacking. Experiments have now been carried out on a highly excited atom in a magnetic field, a system which has come to be regarded as a paradigm for quantum and classical studies because of its simplicity. The spectrum of the atom has revealed orderly progressions in a regime where the classical motion is chaotic, a finding contrary to the accepted notion of how quantum systems behave. In addition, the experimental results appear to point the way to accurate quantum theoretical solutions to a key problem in atomic physics: the behavior of a simple system which lacks an underlying symmetry.

Hydrogen atoms in the gas phase have been cooled to a temperature of 800 microkelvin. A dilution refrigerator was used to load the gas into a magnetic trap. The temperature of the atoms was then reduced by evaporative cooling. The complete energy distribution in the gas can be measured at any stage of the cooling process. The temperature achieved is already comparable to the theoretical limit that can be attained for hydrogen by the competing method of laser cooling. However, the evaporative cooling technique should be applicable to atomic hydrogen down to about 30 microkelvin, a temperature low enough to observe the Bose-Einstein transition in a gas of density 10^{14} atoms/cm³.

Biomedical studies designing and engineering laser-induced fluorescence spectral catheters, and developing fluorescence based algorithms for the diagnosis of atherosclerosis in the cardiovascular system are underway. In these studies, endoscope compatible fiber optic catheters are used for spectroscopic study of laser-induced fluorescence of normal and atherosclerotic arteries in vivo and in vitro. The contributions of individual fluorophores within artery wall in the 476 and 306 to 308 nm laser induced fluorescence of normal and atherosclerotic artery are identified, and a simple mathematical algorithm is utilized to extract diagnostic parameters. Classification schemes using the model parameters are able to categorize correctly atherosclerotic arterial lesions in over 90 percent of the cases. Using a multi-fiber optic catheter, spectroscopic images have been obtained of human coronary artery during bypass surgery. These images clearly delineate regions of normal and atherosclerotic tissue. Molecularly based algorithms such as these will allow the progression of the disease to be followed and assessed. In addition, a laser angioplasty system utilizing fluorescence spectroscopic guidance is currently being constructed.

Sub-Doppler resolution spectroscopy has been demonstrated on very short-lived nuclear isomers using the laser-induced nuclear orientation (LINO) technique, in which optical pumping is used to align the nuclei, producing anisotropy in the angular distribution of γ -rays which they subsequently emit. The width of this sub-Doppler signal is 90 MHz, nearly 1/10 that of the 850 MHz width of the Doppler limited signal. This technique is being utilized to measure the quadrupole moment of $^{85\text{m}}\text{Rb}$ (1.0 μS), by resolving its narrowly spaced D2 spectrum.

Experiments for studying vacuum radiative level shifts and spontaneous emission line widths of an atom in an improved optical resonator have been performed. Such experiments have revealed the largest line width changes to date. In addition, energy exchange between the atom and resonator, viewed as two coupled oscillators, has been observed and the coupling constant ("vacuum Rabi frequency") has been measured. Further experiments may reveal direct observation of this coupling as well as study many atom cooperative effects in optical resonators.

2. Condensed Matter Physics

The collaboration between MIT and Brookhaven in the U.S. and three Japanese laboratories to search for the mechanism of high- T_c superconductivity has continued to be very successful. Neutron scattering experiments at Brookhaven have yielded surprising new features that are clarifying the connection between the magnetic properties and superconductivity. The spins on the Cu ions in the superconductors are found to be canted, rather than antiparallel, relative to their nearest neighbors. It was also found that the amplitude of inelastic spin excitations is diminished as the temperature is lowered, showing that these excitations are closely related to the superconductivity. In separate experiments at MIT it was shown that the conductivity, like the magnetism, is two-dimensional. All these new features must be explained in any complete theory of the superconductivity.

Detailed measurements of the transport properties of epitaxial thin films of the high-temperature superconductor $\text{YBa}_2\text{Cu}_3\text{O}_7$ have extended our fundamental understanding of the critical currents and superconducting vortex motion in these systems. These measurements were the first to be able to test recently proposed models of flux creep as a function of applied current, magnetic field, temperature and field orientation. Thermally-activated flux creep is prominently observed, and in large part can explain the magnitude and temperature and field dependence of the observed critical currents. Furthermore, within this interpretation, the vortices exhibit finite-range correlations consistent with correlated motion of flux bundles even at 77 K.

Thin films have been synthesized of the high T_c superconducting compound $\text{Bi}_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_x$ ($T_c = 110$ K) without the addition of lead impurities, a situation unattainable in bulk materials. These films possess large grains, which together with lithographic techniques will enable the first detailed transport measurements to be made on a single crystal of this phase.

A theory of the high T_c oxide superconductors based on strongly correlated electronic models has been examined. The exchange constant J between the local moments on the copper atoms sets the energy scale of the problem. The effect of next nearest neighbor hopping in the disordered antiferromagnetic state causes a strong tendency towards superconductivity.

The conductivity of electrons has been studied in silicon field-effect and GaAs heterojunction transistors which are so narrow that the electrons in them can move in only one dimension. The devices were fabricated with the goal of exploring what new behavior would be manifested by a truly one-dimensional electron gas. The results were very surprising. At low temperatures the conductance oscillates periodically as a function of the density of electrons in the conducting channel. This oscillatory behavior and concomitant nonlinear dependence of current on voltage indicate that the electrons in the narrow channel condense at low temperature from a gas into a crystalline state. Such a Wigner crystal has never before been clearly demonstrated in a solid because for two- and three-dimensional systems it occurs at too low an electron density.

One of the most extensively studied liquid crystal series is the terephthal-bis-(4n)-alkylanilenes (TBnA). For $n \geq 5$ these exhibit smectic C, smectic F and smectic G phases. The smectic C phase has two-dimensional (2D) fluid in-plane order, while smectic F is believed to be a 3D hexatic and smectic G is believed to be a 3D crystal with positional and orientational long range order. In TB5A the SmC-SmF transition is first order while for $n = 6$ and 7 it may be second order. This is therefore an ideal system in which to study hexatic liquid crystal phases and phase transitions. Single domain hexatic S_F films have been grown as well as single crystal S_G phases for $n = 5, 6, \text{ and } 7$. The growth of the hexatic phase was studied in detail using x-ray scattering techniques. The experiments verify the MIT model for the growth and structures of hexatic liquid crystals.

Noble metal surfaces represent ideal systems for studying surface reconstruction and surface roughening. The former corresponds to a change in the symmetry of the surface compared to the bulk while in the latter the surface spontaneously "roughens" via the nucleation of steps and islands. Recent theory has suggested that there may be a complicated interplay between roughening and deconstruction effects. A high resolution synchrotron x-ray study of the deconstruction of a Au (110) surface has been carried out.

Depending on surface treatment the sample exhibited as the equilibrium phase either a 1×2 or a 1×3 reconstruction; these correspond to 2 atom or 3 atom (111) microfacets. Complete data are currently available for the 1×3 reconstruction which turns out to be quite novel. Specifically at about 475°C , the surface period becomes incommensurate with the bulk while the surface itself simultaneously roughens and loses its long range coherence. This is thought to be due to a spontaneous proliferation and 1 atom and 2 atom high steps. Such behavior has not been seen previously in any surface study. Further synchrotron x-ray studies are necessary to elucidate fully this new kind of surface transition.

A definitive x-ray diffraction study of the (100) facet of Au has been carried out between room temperature and the melting point. From this, a consistent description of the structure has emerged for the first time. At low temperatures, the surface exhibits a novel atomic rearrangement in which the topmost layer of atoms forms a near hexagonal structure on top of the crystallographic planes of square symmetry. The near match between 5 square unit cells and 6 hexagonal gives rise to a surface buckling, which has been shown to extend several layers into the bulk. For temperatures $T < 900 \text{ K}$, the hexagonal lattice is rotated away from a symmetry axis of the bulk by 0.8° . At $T = 90 \text{ K}$, this rotation angle drops discontinuously to zero. Most interestingly, at $T = 120 \text{ K}$, there is a surface melting transition, in which the layers near the surface progressively lose in-plane translational order as the surface is approached. This is the first observation of surface melting on such a low-index (high areal density) facet. It remains to be determined whether the surface melting is a consequence of the instability which leads to the reconstruction or whether it is generic to f.c.c. (100) metal surfaces.

A theory has been introduced that predicts that the ground state surface of a faceted crystal is not always atomically smooth and uniform as previously expected and that for a large class of materials this surface is unstable to the spontaneous formation of elastic-stress domains.

Theoretical electronic structure calculations have been used to identify, for the first time, a defect with a negative effective correlation energy in the chalcogenide materials. It is found that in As_2Se_3 two noninteracting neutral Se antisite defects are unstable toward the formation of a pair of noninteracting oppositely charged Se antisites.

A new microscopic model of heteroepitaxial growth has been introduced using GaAs on Si(100) as a prototype. This model takes into account specific features of surface topology, predicts conventional 2D epitaxy should be inhibited, and provides a fundamental explanation for the 3D nature of the initial stages of growth.

Randomness in the coupling constants of a system had been regarded as a rather benign form of quenched disorder. However, within the last year, renormalization-group arguments and calculations have shown that such randomness has a drastic effect on multicritical phase diagrams: Multicriticality (tricriticality, critical endpoints, bicriticality, etc.) is totally eliminated in two dimensions and strongly depressed in temperature in three dimensions. A random-field mechanism, operative even in the absence of random fields, causing these phenomena has been identified. Another consequence of this mechanism is that phase transitions in q-state Potts models and related structural phase transitions are converted from first order to second order, under coupling-constant randomness. Thus, q_c , the number of states above which the transition is first order, is changed from 4 to ∞ in two dimensions and is increased from 2.6 in three dimensions. The latter raises the interesting possibility of observing novel second-order structural phase transitions.

During the past year a systematic experimental study of the Equation of State of protein solutions in the vicinity of the critical point has been undertaken. These investigations are important because they provide a fundamental scientific basis for understanding the phenomena of cold cataract in the mammalian lens and also related phenomena, such as the phase transition in hemoglobin-S solutions responsible for sickle cell disease. The program will permit one to predict the macromolecular properties of proteins and the surrounding ionic solution which establishes the conditions for phase separation. In this way, one can design methods for the systematic suppression of phase separation or the induction of phase separation in protein solutions. Such knowledge will be of great importance, both in the control of disease connected with phase separation phenomena, and will also be useful in the development of technical methods for protein purification and characterization using x-ray crystallography.

An exploration of electrochemical noise processes utilizing a new technique pioneered for corrosion studies, superconducting magnetometry. A mathematical treatment was developed to link the noise processes to the interaction current flowing between the electrodes. An analysis technique, formulated to provide a means to measure the charge transfer resistance, has been filed as a patent. This analysis technique offers the capability to distinguish between passive and active fluctuations. Collaboration is being initiated with industry to develop a prototype superconducting magnetometer optimized for corrosion investigations.

3. Plasma Physics

Construction of Alcator C-MOD, a high field, compact tokamak facility, is proceeding. This device, which is based on the successes of its predecessors, Alcator A and Alcator C, adds strong shaping and magnetic divertor capability. Alcator C-MOD will serve as the focus of our ongoing investigations into the transport physics of magnetically confined high temperature plasmas which are at or near the conditions necessary to achieve a controlled thermonuclear burn. A major portion of the scientific efforts is presently devoted to the design and preparation of the sophisticated diagnostic systems which will be used to determine the properties of the plasma. Techniques being employed include laser scattering, interferometry, reflectometry, photon and particle spectroscopy, bolometry, and electric and magnetic probes. First operation of the device is scheduled for the end of calendar year 1990.

MIT is collaborating with the Princeton Plasma Physics Laboratory on transport and fueling experiments at the TFTR tokamak in Princeton, utilizing a carbon/lithium pellet injector which was designed and built at MIT. The injector, which presently installed at TFTR, will also be used to measure internal magnetic field, and thus current density profile, by means of Zeeman polarimetry on the Li^+ emission from the pellet ablation cloud. Experiments are scheduled to begin in July, 1989, and continue for two years.

The next generation of particle accelerators such as RFLINACS will require novel high power (100 MW), high frequency (10 GHz) drivers, which will replace the conventional klystron. The cyclotron autoresonance maser (CARM) is an interesting candidate. The cyclotron autoresonance maser has been subjected to extensive theoretical studies and numerical simulations. However, unlike the gyrotron and the free electron laser, its capabilities as a source of coherent millimeter wavelength radiation remain virtually untested in the laboratory. So far, only CARM oscillator experiments have been reported in the literature. The coherent radiation generation group at MIT is the first to have designed, constructed, and tested a CARM amplifier. To date, measurements made at a frequency of 35 GHz yield a small signal gain of 90 dB/m and a saturated power output of 10 MW. The corresponding electronic efficiency is three percent. Experiments are in progress with the view of optimizing power output and RF efficiency by improving electron beam quality, and by tapering the guide magnetic field. Plans are underway for scientists from the Lawrence Berkeley Laboratory to test various LINAC accelerating models on the device.

Experimental Nuclear and Particle Physics Division

1. Medium Energy Nuclear Physics

a. Few-body systems

The electromagnetic structure of the simplest nuclei, those amenable to microscopic theoretical analysis based upon the best available models of the nuclear force, continues to be a major focus of the Bates research program. Data taken on the three-nucleon "mirror" nuclei led to the conclusion that microscopic calculations successfully reproduce the ground-state correlations in these nuclei but fail to reproduce the time-dependent response. This has been reinforced by data on the four nucleon system. Another difficult experiment, this one examining the polarization observables in electron scattering from deuterium, has been completed and, upon analysis, will provide the first full characterization of the ground state charge structure of the most elementary nucleus. This experiment is thought to be a key one in our attempt to identify the relevant degrees of freedom in nuclear dynamics at length scales below 10^{-13} cm. In the near future, additional experiments on these simple systems are envisioned. For example, an experiment to measure the short distance magnetization distribution in the two nucleon system will be carried out. A set of measurements examining, in coincidence, the distribution of protons ejected from deuterium by the electron beam will be advanced. Such measurements demand the development of entirely new experimental capabilities (e.g. out-of-plane magnetic spectrometers being developed by an MIT-Illinois Collaboration) and are characteristic of the types of programs which will be central to research using the South Hall Ring now under construction.

Richard Milner, who has just completed his first year as Assistant Professor, was recently appointed a Presidential Young Investigator. His current efforts are focussed on developing polarized ^3He gas targets in order to study neutron structure. A major accomplishment was a successful test of the polarized target in a high current electron beam. A quasielastic scattering measurement at Bates will allow study of the neutron charge distribution. A subsequent experiment under development for the Hamburg Electron Synchrotron at DESY (HERA), a high energy storage ring under commissioning in Hamburg, will measure the deep inelastic neutron spin structure function.

b. Electron, Proton Coincidence Experiments

Electron-proton coincidence experiments continue to be an important program at Bates and several interesting results emerge from the data using carbon as a target. The absorption of energy beyond the quasifree region, appears to require at least three nucleons to explain the population of high excitation of the residual system. This multinucleon phenomenon has been observed in pion absorption as well. In addition, a very large and surprising yield of high energy deuterons has been found, suggesting a new direction for study of nuclear correlations. This is likely to be an important program when the South Hall Ring is operational.

c. Parity

A first generation parity experiment has been completed at Bates by a collaboration involving MIT, Syracuse, Yale, Harvard and other institutions. The experiment measured the asymmetry in scattering of polarized electrons from ^{12}C (a spin zero target). The data are being analyzed. A statistical uncertainty of 1.5×10^{-7} is expected, providing a twenty percent measurement of the asymmetry predicted by the Standard Model. A substantially more ambitious second generation program is now being planned.

d. Experiments in Pion Physics

Most of the work outside of the Bates Laboratory involves pion scattering and pion induced reactions at Los Alamos and at Paul Scherer Institute (PSI). Along with collaborators from other institutions, the MIT group has built a new large-solid-angle multi-particle detector to be used at the Swiss Institute for Nuclear Research for studies of pion absorption in nuclei. These new experiments should reveal whether pion absorption is indeed showing new and interesting physics, perhaps involving quark degrees of freedom, as several recent experiments have indicated. The first experiments will take place later this year.

e. South Hall Ring

The Bates research program has done much to frame the questions and to establish the experimental basis for the future electronuclear studies needed to advance nuclear physics along new directions. The new capabilities needed have been identified: continuous (CW) beams and full utilization of polarization observables. The South Hall Ring (SHR) project at the Bates Laboratory is an experimental initiative which will provide these capabilities throughout the important energy range accessible to the existing accelerator (i.e., up to 1 GeV). The South Hall Ring will be available for research in 1992. It will be an integral part of the South Experimental Hall using existing beam lines for experiments in the internal target mode and in the extracted beam mode. This is accomplished by using the SHR to manipulate the time-structure of the pulsed beam provided by the accelerator. The conventions construction is well along and should be completed early in 1990. Installation of technical components will start in spring 1990.

In the internal target mode, the electrons are circulated thousands of times through a windowless gas target introduced into the ring. The major benefit of this configuration is that it permits (and requires) the use of exceedingly thin targets, i.e., targets so thin that an insufficient number of interesting collisions would take place if each electron passed through the target only once. There are several advantages to this approach. One is that heavily ionizing reaction products are able to leave the target and reach the detector. This possibility is central to a number of planned experiments, for example, those aimed at a basic understanding of nuclear fission or of the propagation of ions in the nuclear interior. Perhaps the most exciting prospect, however, is that associated with polarization. Advances in laser technology and surface science now make it feasible to produce gases of polarized nuclei of sufficient thickness for internal target use. There is considerable activity in this field, for example, at Argonne, Caltech, Harvard, Indiana, MIT, Oak Ridge, Princeton, and Wisconsin. Such internal target experiments, representing a significant departure from the traditional experimental configuration in electronuclear physics, will require innovative developments advancing both physics and technology. In considering potential developments at Bates, the Nuclear Science Advisory Committee has stressed that the "combination of internal target capability and polarized beams for addressing important new areas...will be unique in the world."

In the extracted beam mode, the SHR will be used as a pulse stretcher. The basic idea is that the SHR will capture each accelerator beam pulse and then "leak" the electrons to the experiment uniformly between pulses. The technical challenge lies in performing the filling and emptying procedures efficiently, rapidly, and yet smoothly. We anticipate a broad program, for example, in exploring nuclear collective motion, in mapping the nuclear spectral function, and in measuring the nuclear pion distribution near threshold. With the South Hall Ring experimental initiative at Bates and the major new facility at the Continuous Electron Beam Facility (CEBAF), the American basic research community will have at its disposal unmatched capabilities built upon novel technologies.

2. Relativistic Heavy Ions

The Heavy-Ion Group is a large part of the E802 collaboration, the first major experiment successfully exploiting the 235 GeV oxygen and 412 GeV silicon beams that have just become available during the last year at the Brookhaven National Laboratory

Tandem/AGS accelerator facility (unique in the US). Using these beams, collisions with heavy target nuclei, from aluminum to gold, offer far higher matter/energy densities than heretofore studied, approximating conditions that may have occurred during the initial expansion of the universe and yielding important tests of Quantum Chromodynamics (QCD), the theory of the strong interaction. In each collision hundreds of particles are produced. The MIT Group designed and constructed the particle tracking system (as well as developed the associated track-reconstruction algorithm) for the multi-particle spectrometer used to study these collisions. Analysis of the produced particle multiplicity and transverse energy flow, as a function of target nuclear size, indicates that the projectiles at this very high energy are indeed stopped during central collisions with the largest nuclei, producing energy densities several-fold higher than in normal nuclear matter. Analysis of the spectrometer data has yielded the provocative result that the production of positive strange mesons (K^+) relative to normal p^+ mesons is threefold enhanced compared to proton induced reactions. Experiments during the coming year will help elucidate the dynamical origin of this result.

The MIT Group is also improving the E802 tracking detector system as well as designing a new system that can exploit the much heavier and energetic (2700 GeV) gold beams that will become available when the AGS booster synchrotron is completed in 1991. This will provide the opportunity to reach even higher matter/energy densities.

3. Experimental Particle Physics

a. Accelerator Physics Collaboration (APC) Group.

The APC Group is conducting experimental research at Fermi National Accelerator Laboratory (FNAL) in Illinois and the Gran Sasso Laboratory (GSL) at L'Aquila, Italy. The Group has recently taken data at FNAL in the world's highest energy neutrino beam, utilizing a holographic bubble chamber. This experiment is investigating a new domain in neutrino physics. 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 make the best search for neutrino oscillations. The Group will also study the production of solar neutrinos and will measure the yearly rate of collapsing stars in the universe. Another objective is the search for point sources in the universe emitting high energy neutrinos.

b. Counter Spark Chamber (CSC) Group.

The CSC Group has been involved in a FNAL-based program of studying the structure of the nucleon and the structure of the weak interaction using neutrinos as a probe. The major focus has been on the analysis of the data obtained to determine the structure functions of the nucleon, as sensed by the weak neutral current, and to make detailed comparisons of the neutral and charged current interactions with the nucleon. The results obtained are consistent with the predictions based on the Weinberg-Salam-Glashow (W-S-G) weak electromagnetic unification theory and the quark-parton model, and have yielded a new precision value of the weak mixing angle. The Group has continued its neutrino studies with Tevatron II, the FNAL 1000 GeV accelerator. We have completed the final experimental run in this program and are now analyzing the data. A measurement of the strange quark component in the nucleon quark-anti quark seen from this data gives the result that the strange quark occurs about half as frequently as ordinary up and down quarks.

In addition, the Group participates in two other major collaborative programs. (1) The use of m mesons at the Tevatron to study nucleon structure and the mechanisms of particle production. The Group has participated in the construction of a spectrometer to be used in these studies. The first data has been obtained with this system and it is now under analysis. (2) The use of 50 GeV $e^+ e^-$ colliding linac beams (Stanford Linear Collider) at the Stanford Linear Accelerator Center (SLAC) to investigate the physics of the intermediate vector boson Z^0 . The Group is collaborating in the construction of an advanced detector, called the SLAC Large Detector (SLD), which will exploit the new energy region to investigate a number of physics issues. In particular they will search for Higgs particles produced in the decay of the Z^0 . The SLD program is the major group effort for the foreseeable future. The detector is now being assembled and the new accelerator is now yielding about 10-20 Z^0 /day.

c. Lepton Quark Studies (LQS) Group.

The LQS Group is continuing their participation in the construction of the Central Drift Chamber for the SLD detector at SLAC. This detector, when complete, should excel in vertex measurement and particle identification: two features which enhance the

efficiency for the search of new particles such as the Higgs boson and heavy-quark mesons. The group also continues their interest in detector development for next generation accelerators such as the Superconducting Super Collider (SSC) and is involved in a laboratory-wide (LNS) proposal for such studies. Analysis of early data taken at SLAC on the photoproduction of hadrons from protons at 20 GeV is continuing. This large database contains reactions with abundant production of vector mesons. In particular there is also a large number of charmed mesons available for study.

d. Electronic interactions (EMI) Group.

The EMI Group is building a large precision detector at the 200 GeV electron-positron accelerator, LEP, in Geneva, to be operating in 1989. The Group has been leading this large construction effort, which involves 350 Ph. D. physicists from 12 nations, to build a large detector to measure photons, electrons, and muons precisely. The experiment is the first large-scale collaboration between physicists from the Soviet Union, The People's Republic of China, and the United States. The construction of this experiment is proceeding according to schedule and will be ready for data-taking by the time of the first LEP beam. The purpose of this experiment is to understand the origin of the masses of elementary particles, to search for the 6th quark and to probe beyond the standard theoretical models. The precision electron, muon and photon detectors developed for this experiment also serve as proto-type detectors for future high energy colliders, such as the SSC.

e. Proton-Antiproton Collision Group.

This Group is a member of the UA1 collaboration at CERN. After the discovery of the W and Z particles in 1982-83, a large amount of data was collected. This group leads the main analysis effort in search for the top quark. Other analysis activities include the further study of properties of the Z and W, the search for new leptons with masses above $41 \text{ GeV}/c^2$, the study of monojets, the search for supersymmetric particles, and the mixing of B^0 and anti-B mesons. The Group is planning to expand its emulator system for analysis by an order of magnitude to accommodate much greater data yields anticipated in upcoming UA1 experiments. The Group also plays a major role in the construction of the new UAI Uranium-Tetramethylpentane Calorimeter. In particular, this group is in charge of the design and construction of the Positron Detector for the new calorimeter. This state-of-the-art calorimeter has implication for future detectors at SSC.

Theoretical Physics Division

1. Particle Theory

This has been a very active year, with members of the group making marked progress and becoming involved in lively controversies. Research ranges from questions of interpretation of recent and proposed experiments using the well-established standard model, through cosmological conjecture, to exploration of the beautiful connections between quantum field theory and geometry.

Recent measurements by the European Muon Collaboration of deep inelastic scattering of polarized muons from protons has triggered a theoretical debate over the structure of the spin content of the proton. Members of the group have been in the forefront of this controversy. There is still much to be learned here, and a program of measurements of basic quark matrix elements has been suggested. The prospect of deep inelastic scattering measurements with polarized nuclear targets has stimulated theoretical analysis and the discovery of new structure functions which would measure the gluon content of a nucleus not associated with individual protons and neutrons.

The question of the role of different types of cosmic strings in the evolution of the universe involves fascinating problems of particle physics and astrophysics. The dynamics of a network of cosmic strings in the early universe has been the subject of a sophisticated computer simulation. Preliminary results are very promising. A subject of keen controversy in early universe physics has been the process which produced the observed excess of baryons over antibaryons. It has been claimed that standard model field theory provides a process which would wash away any baryon asymmetry produced in the very early universe. Members of the group have analyzed the situation and repudiate this claim. To go right back to the beginning of the universe it is necessary to understand quantum gravity. Detailed research has been carried out on the process of production of a whole new universe by quantum tunnelling. This is an attempt to explore simultaneously the basis of the theory and the tools available to calculate the consequences, in a regime where even the fundamental concepts (like time) are subject to controversy.

Though the hope of a few years ago that the theory of superstrings would serve as a fundamental theory has faded somewhat, members of the group have made remarkable progress towards the construction of a field theory of interacting closed strings. The structure required is extremely elaborate but also in a sense very natural. The elegant subject of conformal field theory, an offshoot of progress in string theory and in statistical mechanics, has seen much technical advance.

Further proof, if any was needed, of the deep and beautiful connections between quantum field theory and modern geometry, has been found. Three dimensional topological field theories, which members of the group played a large part in inventing and studying, have been shown to have remarkable properties of great interest in both physics and mathematics.

2. Nuclear Theory

Nuclear theorists at MIT address a broad range of problems in contemporary nuclear physics, combining 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 physics and the role of QCD effects in nuclei is a growing focus of research, both because of its fundamental significance and the unique resources at the interface between nuclear and particle physics in the Center for Theoretical Physics. Because QCD is presently intractable analytically, our research addresses hadronic physics from a number of complementary viewpoints which focus on different aspects of the problem. One major effort is to calculate the properties of the nucleon numerically in lattice gauge theory in order to test and distinguish between the various contemporary quark, bag, and soliton models. Studies of QCD and confinement explore the role of color deformed states, the formal similarity to Anderson localization, the quantum mechanics of a multiply connected space, the ground state wave functional of pure Yang-Mills theory, many-body techniques appropriate to large N_c , and classical Yang-Mills solutions. The role of antisymmetry in modifying the quark momentum distribution in the nucleus has been demonstrated and QCD in two space-time dimensions has been used to test techniques and approximations for four dimensions. Chiral models have been used to study radiative decay of hyperon resonances, to elucidate the spin content of the proton, and to explore the strange quark content in the proton.

Relativistic heavy ion collisions comprise another area of growing activity, motivated by the unique opportunity they provide for fundamental exploration of new regimes of matter, new data from Brookhaven and CERN, and the experimental effort in this field at MIT. A flux tube model has been developed in which two inter-penetrating nuclei become color charged and generate a strong confined color field which creates quark-antiquark pairs. In this model, the hydrodynamic evolution of the plasma, the non-Abelian classical evolution of the color fields, hadronization of the flux tube, and stopping power have been investigated. Subsequent to the suggestion from this group that J/ψ production could reflect screening in the quark gluon plasma, such suppression was observed in the CERN experiments. Quantitative calculations of the transverse momentum dependence of J/ψ suppression are consistent with the CERN data, and the role of dynamic Debye screening in the plasma and final state interactions in a deconfined phase have been investigated.

Nuclear many-body theory provides the foundation for many aspects of nuclear theory, and has thus been an area of continuing interest. Problems in the quantum theory of collective motion ranging from fission to the quantization of large amplitude vibrations involve periodic solutions to time-dependent mean-field theory. Thus recent efforts have focussed on understanding the nature of periodic solutions to multidimensional classical systems, their implications for quantum chaos and calculating periodic solutions for physical processes. A coherent state representation has been shown to provide a useful bridge between periodic classical solutions and quantum eigenstates. Stochastic techniques have been applied to a variety of nuclear many-body problems ranging from lattice gauge theory to the exact solution non-relativistic models with static interactions. A new stochastic method for Fermions in any spatial dimension has been developed which circumvents the long-standing problem associated with antisymmetry.

Electromagnetic interactions have been a continuing focus of theoretical interest, both because of the unique precision of electromagnetic probes and important new questions in coincidence experiments and polarization observables arising from the Bates program and South Hall ring project. An important development in the study of polarization observables was the discovery of new structure functions for deep inelastic scattering from polarized nuclei. A new formulation of quasielastic electron scattering yields an exactly calculable expression for the corrections to impulse approximation and thus allows quantitative extraction of the nuclear momentum distribution. Other topics include the study of sub-nuclear degrees of freedom in elastic scattering from the deuteron, understanding the nuclear response function and Coulomb sum rule in inclusive inelastic scattering, the study of isospin mixing in parity violation experiments, and investigation of photon and neutrino reactions. Analysis of hadron-hadron scattering using R -matrix theory and the bag model has been used to investigate exotic multi-quark resonances. Activities in intermediate energy physics also include the study of the pion optical potential, pion nucleus scattering, and pion production.

Part of the vitality of the Center for Theoretical Physics arises from broad interests in general problems in theoretical physics. Thus, the nuclear theory group has also addressed such topics as QED in strong fields and finite chemical potential, general lattice field theory, quantum spin systems, and problems in nuclear astrophysics.*

ROBERT J. BIRGENEAU

Cell Culture Center

The Cell Culture Center at MIT was established in 1974 to serve as a facility and resource for all biologists throughout the United States. The mission of the Center is to produce cells and cell products on a large scale in order to allow scientists to conduct basic research that could not be accomplished with the materials and resources in the investigator's own laboratory. The Center is headed by Donald J. Giard, Principal Investigator and Director. Its principal source for funding is the National Institutes of Health (NIH). The Center is unique in the sense that it is the only facility of its kind in the United States which provides cellular material to scientists strictly on the basis of scientific merit, without regard to other factors such as regional location. Its staff works directly with individual scientists on basic research problems and, in addition, conducts an active program in the development of new technologies for large scale animal cell production.

During the period July 1, 1988 to June 30, 1989, the Cell Culture Center provided large batches of animal cells and cell products to more than 60 research groups throughout the United States. Cells were produced in a variety of ways, including roller bottles, suspension culture and microcarrier cultures. More than 10^{13} cells were produced as the demand for cells continued to be high. Examples of projects completed during the past year include:

- 200 liters of HeLa cells for Michigan State University, East Lansing, Michigan; for purification of proteins that bind to mammalian RNA polymerase II.
- Production of kilogram quantities of human lymphoblastoid cells for Harvard University, Cambridge, Massachusetts; for purification of Class II histocompatibility antigens.
- 400 grams of lymphoblastoid cells for Massachusetts Institute of Technology, Cambridge, Massachusetts; for studies on the interaction of HLA-2 and HLA-B7 proteins with antigen-specific receptors on Cytotoxic T lymphocytes.
- 288 liters of Drosophila Kc cells for Brandeis University, Waltham, Massachusetts; for studies on transcriptional control of the yolk protein (YP) and α -tubulin genes.
- 30 liters of K562 cells per month for The Children's Hospital, Boston, Massachusetts; for studies on the mechanisms by which fetal hemoglobin synthesis is controlled.
- 200 roller bottles of a renal carcinoma line (SK-RC-28) for the University of Chicago, Chicago, Illinois; for studies on the reactivities of human monoclonal antibodies derived from patients with primary lung cancer.
- 600 roller bottles of L-6 muscle cells for Cornell University, New York, New York; for purification of a growth factor in the brain.
- 50 liters of HeLa for Princeton University, Princeton, New Jersey; for characterization of the cellular transcription factor E2F.
- 80 grams of human lymphoblastoid cells (JY) for Rice University, Houston, Texas; for studies on the antigen-independent adhesion of cytotoxic lymphocytes to potential target cells.

- 100 liters of HeLa cells for Massachusetts General Hospital, Boston, Massachusetts for purification and characterization of nuclear proteins in regulation of the human proenkephalin gene.

A recent decision by MIT not to continue to provide space for the Cell Culture Center operation will result in its closing at the end of its current NIH grant period on March 31, 1990. During its sixteen years of operation, the Center will have provided hundreds of laboratories throughout and outside the United States with cellular materials permitting research that has resulted in literally thousands of scientific publications. In addition, to its production services, the Center has continuously been involved in other activities including: 1) A cell sorting service; 2) Research and Development focusing on large-scale animal cell technology; 3) Training students in cell culture techniques. At this date, it appears likely that at least some of these services will continue to be available in the future, since officials at NIH have indicated their intention of supporting a cell production facility at another location.

DONALD J. GIARD

Center for Cancer Research

The Center for Cancer Research was established in 1973 to study fundamental biological processes related to the human disease of cancer. The goals of its research can be generally stated as developing an understanding of (1) the genetic basis of cancer, (2) how alterations in cellular processes affect cell growth and behavior, and (3) how the immune system develops and recognizes antigens. These goals are related to the three major research programs, oncogenes and mammalian genetics, cell biology, and immunology. Currently 158 people work in the Center who are distributed between the research laboratories of 11 faculty. The total research activity in the Center has grown by 20% over the past year. This growth exclusively represented expansion of ongoing programs.

Several honors were bestowed upon faculty members of the Center in the past year. These reflect the esteem that others have for the accomplishments of the faculty. Dr. Richard Hynes was elected Fellow of the Royal Society of London. Drs. Earl Ruley and Brent Cochran were appointed to the Latham Family and the Pfizer Career Development Professorships. Dr. Phillip Sharp received two major awards, the 1988 Louisa Gross Horwitz Prize and the 1988 Albert Lasker Basic Medical Research Award. He shared both awards with Dr. Tom Cech of the University of Colorado.

The Center continues to evolve in structure with expansion of research programs. Consolidation of two kitchen facilities into one facility in new space made it possible to expand the research space of Drs. Hynes and Solomon. Both of these investigators originally joined the faculty as assistant professors in the area of cell biology. In the intervening years, their research has grown in importance and volume. Both are now full professors and were in critical need of more space. The same was true of Dr. Housman whose program in human genetics has greatly expanded in importance. Additional space was added to his laboratory in 1988. Two new research facilities were added to the Center during the past year. A biopolymer laboratory was developed with resources from the Center, the Department of Biology, and the Howard Hughes Medical Institute. This facility synthesizes gene fragments, protein fragments, and does sequencing of micro quantities of protein for the various research programs in the Center. The second facility has the expertise and equipment to produce transgenic mice for research. These mice are genetically engineered with the insertion of foreign genes into their germline. Both of these facilities will greatly enhance the research in the Center.

A discovery made in Dr. Susumu Tonegawa's laboratory in 1985 has grown in importance with further research during the past year. Dr. Tonegawa's laboratory, in collaboration with Dr. Herman Eisen's laboratory, discovered a novel T-cell receptor gene family γ . The human immune system is comprised of two types of cells, T and B cells. The T cells control the immune response and also can kill other cells by recognition of a foreign antigen displayed upon their surface. This antigen is displayed in a complex with the major histocompatibility protein on the surface and this complex is recognized by a heterodimeric receptor protein on the surface of T cells. Most T cells have heterodimeric receptors formed by proteins encoded by the α and β gene families. Dr. Tonegawa also first identified genes encoding the α receptor. When his laboratory described the isolation of the γ gene family, the field of immunology was greatly puzzled. Subsequent studies have shown that a novel subset of T cells exist which have heterodimeric receptors formed of proteins encoded by γ and δ genes. Recent results from Dr. Tonegawa's laboratory has shown that the $\gamma\delta$ receptors are highly diversified in structure and thus probably recognize a diverse set of foreign antigens. These T cells are preferentially found in the epithelial layer of the body and perhaps destroy emerging cancer cells in this part of the body. Dr. Tonegawa has also shown that T cells with the $\gamma\delta$ receptors recognize antigen presented on other cell surfaces in a complex with the TL cell surface protein. Interestingly the TL protein resembles the major histocompatibility protein which is specific for the $\alpha\beta$ receptors. The role in the body of this new type of T cell bearing $\gamma\delta$ receptors is not yet clear. However, Dr. Tonegawa's results strongly suggest these cells are functional and critical parts of our immune system.

The strength of the Center remains its attractiveness as an environment for the training of young scientists. The Center currently has 39 graduate and undergraduate students and 61 postdoctoral fellows/associates. The vast majority of these fellows are supported by national and international competitive fellowships. The Center also benefited from a number of faculty-rank visitors during the past year: Hiroyuki Aburatani of the Tokyo University School of Medicine; Paul Billings, Myles Brown and Daniel Haber of the Dana Farber Cancer Institute; Paula Fracasso and Michael Rabin of the Beth Israel Hospital; Andrzej Krolewski of the Joslin Diabetes Center; Judith Lieberman of the Tufts New England Medical Center; and Eugene Marcantonio of the Brigham and Women's Hospital.

PHILLIP A. SHARP

Center for Space Research

The Center for Space Research (CSR) conducts an active program of research in astronomy, space science, and related technology, with emphasis on experimental and theoretical investigations in support of various National Aeronautical and Space Administration (NASA) flight missions. Although the primary source of support comes from NASA, a significant fraction of the research program is sponsored by the National Science Foundation (NSF) and the Department of Defense (DOD). Specific areas of research include gravity-wave, X-ray, optical, radio, and radar astronomy; geodesy; theoretical and experimental space plasma physics; planetary surfaces and atmospheres; and the life sciences. The current and near-future NASA flight program contains a number of missions in which CSR is heavily involved: the Voyager-2 mission to the outer planets (VGR2), the Magellan Venus Radar Mapper mission (MGN), the Cosmic Background Explorer (COBE), the Advanced X-ray Astrophysics Facility (AXAF), the X-ray Timing Explorer (XTE), the Space Transportation System (Shuttle) Spacelab series, and an investigation of Earth's plasma environment as part of the International Solar Terrestrial Physics Program (ISTP). Two new "mission-of-opportunity" programs, in which CSR will play a crucial role, have also been recently initiated by NASA. These are: ASTRO-D, a Japanese X-ray satellite for which CSR will supply an imaging detector, and the High-Energy-Transient Experiment (HETE), a small, inexpensive satellite under MIT's direct control. CSR also supports a program of theoretical astrophysics and of optical observations carried out at the Michigan-Dartmouth-MIT (MDM) Observatory (whose operations are partially managed by CSR as MIT's agent). An overview of CSR activities during the past year follows; all faculty are in the Physics Department unless otherwise noted (AA refers to the Department of Aeronautics and Astronautics; EAPS to the Department of Earth, Atmospheric, and Planetary Sciences; EECS to the Department of Electrical Engineering and Computer Sciences).

RESEARCH IN X-RAY ASTRONOMY

Analysis of Data from Satellite X-ray Observatories. The only orbiting X-ray observatory currently operating is the Japanese "GINGA" satellite, which, fortunately, is available for foreign guest usage. During the past year, the MIT X-ray group has been very successful in obtaining observing time on GINGA. Since this group also remains in charge of several of the X-ray archives from past missions and has ready access to the others, it has been able to preserve its research momentum in the field while preparing for the next generation of space missions to be launched here and abroad in the 1990's.

Professor Hale Bradt and Dr. Ronald Remillard are completing a major catalog of X-ray sources identified by HEAO-1, and continue to investigate the nature of these sources using observations at other wavelengths. Professor Claude Canizares and his colleagues are preparing a catalog of X-ray spectra from the Einstein Observatory (HEAO-2) spectrometer. Specific studies of the spectra of supernova remnants, clusters of galaxies and active galaxies are also being pursued, as are optical observations of these objects using the new MDM Observatory. Professor Walter Lewin and his collaborators at MIT and abroad are investigating the nature of low-mass binary X-ray sources by analysis of the quasi-periodic oscillations and bursts seen in their X-ray emission, using data from the European X-ray Observatory Satellite (EXOSAT). In continuing research, Professor Lewin and his coworkers are using GINGA observations made simultaneously with radio observations at the Very-Long Baseline Array (VLA) in New Mexico, and have successfully observed correlated phenomena. Professor George Clark and his student, working in collaboration with Dr. Fumiaki Nagase and others of his colleagues at the Institute of Space and Aeronautical Sciences (ISAS) in Tokyo, are studying the atmospheric structure of the primary stars using GINGA observations of eclipsing X-ray binaries. This group has recently reported the discovery of a cyclotron absorption line in the spectrum of the binary X-ray pulsar 4U1538-52.

Advanced X-ray Astrophysics Facility (AXAF). Professor Canizares and his team are completing the definition study of a High-Energy Transmission Grating Spectrometer (HETG) and a Bragg Crystal Spectrometer (BCS). HETG represents a collaboration with Professor Henry I. Smith (EECS), and has been approved for flight on AXAF, while BCS is being held as a reserve option pending final assessments of total AXAF payload costs next year. Laboratory demonstrations of both instruments have verified their performance.

During the past year, the AXAF Charge-Coupled Device (CCD) Imaging Spectrometer (ACIS) experiment (MIT's second AXAF entry) has continued in the detailed design and definition phase under the leadership of Dr. George Ricker (CSR) as the MIT Deputy Principal Investigator. While the Principal Investigator (PI), Professor Gordon Garmire, is at Pennsylvania State University, CSR has overall technical and management responsibility for this experiment. Lincoln Laboratory is participating with CSR in the design and fabrication of the ultra-low-noise detectors for this instrument, and has successfully furnished the prototype version of the high-resistivity sensors which are being evaluated at CSR over a broad range of X-ray energies. In January 1989, NASA chose to designate ACIS as a "core instrument" for AXAF, which ensures that it will indeed be carried on the spacecraft as part of the initial focal plane configuration, when it is launched in 1997.

ASTRO-D Mission. This program is a joint undertaking of CSR (through NASA) and ISAS (in Japan). Under the terms of the international agreement, CSR will provide a focal plane instrument incorporating two arrays of ultra-low noise CCD X-ray detectors for launch on a Mu-3-SII rocket by ISAS from Kagoshima Space Center in February 1993. Dr. Ricker is the PI for the ASTRO-D CCD instrument and, as in the AXAF mission, Lincoln Laboratory is participating with CSR in the design and fabrication of the CCD sensors. Following launch of ASTRO-D in 1993, members of the X-ray astronomy group at MIT will join with the ISAS team in carrying out and analyzing observations of cosmic X-ray sources using ASTRO-D.

High Energy Transient Experiment (HETE). HETE is a low-cost "mission-of-opportunity" concept which was presented to NASA by CSR as an unsolicited proposal in February 1987. NASA has adopted HETE as a "new start" in FY 1990, leading to an expected launch in FY 1993/1994. HETE will search for bright transient emissions from astronomical objects over a very broad energy interval, covering the ultra-violet (~5-eV), X-ray (~10-keV), and gamma-ray (~1-MeV) spectral ranges. The primary objective of HETE is to reveal the basic nature of enigmatic celestial gamma-ray bursts by observing their precise locations and broad-band spectral properties, and to probe the underlying physics of the emission which takes place under exotic conditions of temperature, density, and magnetic field. The HETE instruments will be mounted on a novel "mini-spacecraft", which will be ejected from a Get-Away Special (GAS) canister carried into low earth orbit by the Shuttle. Because of the small mass of HETE (~100 kg for spacecraft plus instruments), and its use of low cost management, development, and launch techniques, it is being referred to as a "Cheapsat." Dr. Ricker is the PI for the HETE consortium, which also includes scientists from Los Alamos National Laboratory, the University of Chicago, CNES/CESR (Toulouse, France) and CNIE/IAFE (Argentina).

X-ray Timing Explorer (XTE). This effort represents a relatively inexpensive NASA X-ray astronomy satellite program that is scheduled for launch in late 1994 to study the time variability of celestial X-ray sources at time scales ranging from milliseconds to years. A group under Professor Bradt is responsible for one of the three experiments on XTE, namely the All-Sky Monitor (ASM) that will be used to detect the appearance of new X-ray sources or changes in the intensity of existing sources. As part of this program, CSR is carrying out laboratory studies of position-sensitive detectors. MIT is also responsible for building an onboard processing system to efficiently compress digital data from both the ASM and other experiments, in order to reduce the demands on the volume of telemetered data. The instrument will enter its final design and fabrication phase in November 1989.

Michigan-Dartmouth-MIT (MDM) Observatory. The MDM Observatory, located on Kitt Peak near Tucson, Arizona, is operated jointly by the University of Michigan, Dartmouth College and MIT (CSR) and comprises both the new 2.4-meter Hiltner telescope that was dedicated in April, 1989, and the older 1.3-meter McGraw-Hill telescope. New test equipment has been developed for the Hiltner telescope, and its f/7.5 secondary is now refigured with substantial improvement in image quality. Both the Hiltner and the McGraw-Hill telescopes are heavily oversubscribed during the moonless "dark time" of each month.

Much of the work at MDM this year involved searches for the optical counterparts of stars, galaxies and clusters of galaxies initially discovered at other wavelengths. Professor Bradt, Dr. Remillard and students Grossan and Silber sought to characterize the luminous cataclysmic variables and active galactic nuclei originally discovered in the HEAO-1 hard X-ray survey. Professor Canizares and students searched for coronal iron line emission from gas in clusters of galaxies. Professor Burke and students Conner, Lehar and Heflin identified galaxies associated with radio sources in the MIT-Greenbank 5 GHz Survey. Dr. Ricker and student Luppino identified distant clusters of galaxies associated with steep-spectrum radio sources. Drs. Ricker and Vanderspek and student Mock sought the optical counterparts of gamma-ray "bursters". Professor Binzel (EAPS) began a comparative study of near-Earth and small main-belt asteroids.

Explosive Transient Camera (ETC). This MIT facility, colocated with the MDM Observatory on Kitt Peak, is designed to search the entire night sky for brief flashes of light suspected to be emitted concurrently with high-energy gamma-ray burst events. Fully automated operation began in May, 1987, under the supervision of Drs. Ricker and Vanderspek. Routine operation has continued through 1989. Receiving particular attention is the source GB790107, a recently discovered *recurrent* gamma-ray burster that has produced over 100 brief bursts of radiation above 20 keV in energy during the past eight years.

RESEARCH IN SPACE PLASMA PHYSICS

Interplanetary and Magnetospheric Plasmas. The space plasma group, headed by Professor John Belcher with Professor Ralph McNutt and Dr. Alan Lazarus, is continuing the analysis and interpretation of data received from the earth-orbiting IMP-8 satellite and from the Voyager-1 and -2 interplanetary spacecraft, now traveling through the outer solar system. With Voyager 2 soon to undergo its last planetary encounter (Neptune, on August 25, 1989), the group is heavily involved in intensive planning for both the

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encounter and the subsequent interstellar mission. After passing Neptune, Voyager 2 turns southward but retains a significant outward velocity that will eventually take it through the heliopause, where the plasma environment is no longer dominated by the solar wind. There is great interest in comparing results to be obtained by Voyagers 1 and 2 with the data being supplied by the Pioneer-11 spacecraft at a similar distance from the sun, but nearer the heliographic equator. The effects of variations related to the solar cycle, as well as to the evolution of large-scale plasma structures, are being evaluated.

Work has begun on MIT's contribution to the plasma instrumentation for the WIND spacecraft, an important component of NASA's Global Geoscience Program (a part of ISTP). This experiment will supply data to replace that now obtained from IMP-8, and will serve as the prime monitor of the solar wind for the next decade. The instrument is being built jointly by MIT (the sensor) and Boston University (the electronics).

Theoretical Geoplasma Physics. Activities of the Center of Excellence in Theoretical Geoplasma Research, sponsored by the Air Force Office of Scientific Research under its University Research Initiative, have continued under the leadership of Dr. Tom Chang (CSR), with participation by Professors Belcher and Stanislaw Olbert, and Drs. Geoffrey Chew and David Tetreault. This 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 and participated in a variety of workshops and symposia organized under this program. Support for the Center has broadened in the last year to include contributions from the Air Force Geophysical Laboratory, NASA and Lockheed Research and Development Division.

PLANETARY STUDIES

Magellan Venus Radar Mapper Mission (MGN). This mission, designed to map the entire surface of Venus using synthetic aperture radar (SAR) techniques at a resolution approaching 100m, was launched May 4, 1989, and will reach Venus on August 10, 1990. Professor Gordon Pettengill is the PI for the radar portion of this mission, with support from Professor Sean Solomon (EAPS) and Drs. Joseph Binsack and Peter Ford. Although the SAR data reduction and image production will be carried out at NASA's Jet Propulsion Laboratory, CSR has responsibility for analyzing the ancillary altimetric and radiometric data and for presenting the results as images. As part of this effort, an MGN-dedicated digital processing laboratory has been set up in CSR, with a substantial amount of computing equipment now installed and checked out.

Mars Observer Mission (MO). Professors Pettengill and Solomon (EAPS) are also involved in an experiment using a laser altimeter to determine the topography of Mars at a lateral surface resolution of a few hundred meters, and with a vertical accuracy of several meters. This instrument, being developed at Goddard Space Flight Center, will be carried into orbit around Mars by the Mars Observer spacecraft in 1993.

SPACE GEODESY

The space geodesy group, led by Professor Charles Counselman (EAPS), has demonstrated an improvement in determining Earth-satellite orbits using a method closely related to the astronomical technique known as aperture synthesis. In this demonstration, radio signals from the NAVSTAR Global Positioning System satellites were received at 12 ground stations arrayed in a geometrical progression of spacings.

RADIO ASTRONOMY

Professor Burke continues as PI 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 the Soviets in the mid 1990's.

COSMOLOGY AND GRAVITATION RESEARCH

Gravitational Wave Research. The project to develop and construct a Laser Interferometer Gravitational Wave Observatory (LIGO), involving Professor Rainer Weiss, Dr. Peter Saulson, and their associates at MIT and the California Institute of Technology (CIT), has been substantially altered in direction and scope during the past year, with full technical and fiscal management now centered at CIT under Professor Rochus Vogt (CIT). The group is preparing a major proposal for the final engineering design and construction of two identical sites in the continental US: one on the west coast in California, and one in the east, either in Maine or Louisiana. The site planning is being coordinated with European gravitational wave research groups, in order to optimize the utility of a possible global network. Experimental work at MIT includes assembling a stationary recombined Fabry-Perot interferometer to test new optical concepts for the initial LIGO receivers. Work on an improved low-noise suspension system for the optical mirrors continues, as does work on a facility to test for and minimize the scattering and losses associated with optical coatings and substrates.

Cosmology Research. There are several projects underway in this area at present under the leadership of Professor Stephan Meyer and Dr. Edward Cheng: balloon-borne surveys of the sky at centimeter, millimeter, and submillimeter radio wavelengths to map the synchrotron and free-free galactic emission and to identify possible contamination of the intrinsic distribution introduced by interstellar dust. The group is also heavily involved in the COBE spacecraft mission (scheduled for launch in November 1989 on a Delta expendable rocket) to observe the cosmic background radiation from Earth orbit using a variety of instruments sensitive to the electromagnetic spectrum at wavelengths lying between 200 μm . and 1 cm.

AEROSPACE PHYSIOLOGY AND MAN-MACHINE SYSTEMS

Over the past year, the Man Vehicle Laboratory has continued its work on the interaction of man with his environment. Preparations for the long-delayed SLS-1 (Spacelab-1) flight of the shuttle (currently scheduled for June 1990) are underway, with good prospects for carrying out a number of vestibular experiments. Also approaching are the IML flight (December 1990) with the Mental Workload and Performance experiment and the MVI flight (1991) carrying some of the Laboratory's motion sickness experiments. Other continuing initiatives include the Laboratory's work on basic issues in perception, its work on flight simulation which has shifted focus towards human factors aspects in cockpit automation, and basic work on the etiology of motion sickness. New projects include a major cooperative effort with the NASA Ames Research Center focussing on the use of expert systems as an aid to the space station astronaut and work with the Navy on the effects of high gravity on eye movements, using their centrifuge at Pensacola, Fla. Professor Laurence Young (AA) has returned from sabbatical as director of the Laboratory, assisted by Dr. Charles Oman (AA). Professor Steven Bussolari (AA) will be leaving the Laboratory this summer for a new position at the Lincoln Laboratory.

GORDON H. PETTENGILL

Experimental Study Group

The Experimental Study Group (ESG) celebrated its twentieth year of existence at MIT with an April reunion of over 120 alumni and past staff members. Current and past ESG students participated in a lively two hour discussion about education in the 1970s and 1980s during the reunion weekend. In addition, we hosted alumni who gave talks and demonstrations on the theory and practice of bubbles (Joel Gendler '78), rare musical instruments from around the world (Harry Bochner '76, Arne Langsetmo '76, and Aubrey Jaffer '77), leadership and teamwork (Gregory Moore '73, Peter Fiekowsky '78, and Herbert Lin '73), cooperative living communities (Paul Lieberman '75), and comic a cappella music (Jeff Fried '82 and Mark DeWitt '82). Despite undergoing some structural changes since 1969, it is clear that ESG has remained a community of students and faculty who are interested in exploring alternatives to traditional educational methods, especially those which involve significant participation and initiative on the part of the students. In the words of one alumna, "always I remember the creativity and intelligence with which everything was embraced - the joy of learning that permeated ESG and the caring people who made it happen."

ESG also marked its twentieth anniversary with a change in faculty leadership. Professor Vernon Ingram from MIT's Department of Biology will be succeeding Professor J. Kim Vandiver (Department of Ocean Engineering) as ESG's fourth Director at the end of this year. We applaud Professor Vandiver's success in bringing the strengths of ESG into the forefront of discussions about curriculum and pedagogy at MIT during his five year tenure with us. We will miss his wit, warmth, and good common sense and wish him the best of luck in the future.

STUDENT STATISTICS

ESG enrolled 75 students this year for one or more terms, 39 new freshmen, 14 sophomore transfers, and 21 ESG upperclassmen. Our student body was unusually diverse this year, with 43 percent of our first year students women, 30 percent international students, and 15 percent minority students. Our international students represented a variety of countries, including Zaire, the People's Republic of China, and Columbia.

The 41 sophomores currently registered at MIT who had been in ESG as freshmen earned a median grade point of 4.4. This figure is higher than the corresponding figure for the entire MIT sophomore class for the eighth consecutive year. Sixty-one percent of our sophomores are majoring in the School of Engineering, 32 percent in the School of Science, 5 percent in the School of Architecture and Urban Planning, and 2 percent in the School of Humanities and Social Science.

STAFF AND FACULTY

Professor Vandiver, Director of ESG, and Holly Sweet, Associate Director, oversaw the administration of the program in regular consultation with the ESG Advisory Committee. The Committee is chaired by Professor Alan Davison (Department of Chemistry) and includes representatives from the Departments of Mathematics (Professor David Anick), Physics (Professor Lee Grodzins), History (Professor Arthur Kaledin), and the Dean of the School of Science (Professor Gene Brown). Along with their administrative roles at ESG, both Professor Vandiver and Ms. Sweet taught undergraduate seminars in the fall term under the auspices of ESG. Ms. Sweet also continued her appointment as Lecturer in the School of Science.

The mathematics staff at ESG was headed by Dr. David Witte, a Moore Instructor at MIT who returned to ESG for his second year of teaching, mathematics graduate student David Van Stone, and MIT alumni Susie Lee '88 and Victor Steinbok '87. The physics staff included Professor John King, Professor Emeritus Robert Halfman (past Director of ESG), Dr. Peter Dourmashkin and Craig Watkins (both in their sixth year at ESG), and physics graduate student Daniel Zachary. The humanities staff consisted of Assistant Professor Robin Becker (Writing), Ms. Sweet (Psychology), and political science graduate student Lee Perlman (in his fifth year at ESG). 5.11 Principles of Chemical Science was offered in ESG under the direction of Marya Lieberman '89, who utilized a chemistry text which had been developed two summers ago by a team of three ESG undergraduates (including Ms. Lieberman).

Our chemistry, physics and mathematics staff were assisted by 31 upperclass and graduate student tutors who had been in ESG as freshmen. The 2:1 student to staff ratio which has existed at ESG for many years has allowed us to provide a highly personal approach to education, with the bulk of teaching done through tutorials and small study groups. Our tutors not only did an excellent job teaching our new students but also did well academically, earning a cumulative grade point average of 4.4 by the end of the year.

Our regular academic staff was joined in the spring by MIT alumnus Hrand Saxenian '47, who taught a new undergraduate seminar on leadership and teamwork to both ESG and regular curriculum students.

ACADEMIC DEVELOPMENTS

Several new undergraduate and freshman advisor seminars, offered to all MIT undergraduates, were sponsored by ESG this year under a special grant given by the Dean of the School of Science for curriculum development and innovation. These included one freshman advisor seminar in the fall, 13A02 Vietnam - Reflections on a War (taught jointly by Professor Vandiver and

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Mr. Perlman), and three undergraduate seminars in the spring, SEM065 Non-Violent Political Action (taught by Mr. Perlman), SEM068 The Philosophy of Physics (taught by Dr. Dourmashkin), and SEM069 Leadership and Teamwork (taught by Mr. Saxenian). In addition, SEM051 Sex Roles and Androgyny was co-taught by Ms. Sweet and Mr. Perlman for the fourth consecutive year. Twenty-nine regular curriculum students and 14 ESG students enrolled in one or more of these seminars this year.

Based on the success of Dr. Dourmashkin's spring seminar and on the growing interest at MIT in context and linked subjects, Dr. Dourmashkin and Mr. Perlman will be offering a new 24 unit subject in ESG this coming fall. This course will combine 8.01 Physics with Philosophy of the 17th and 18th Centuries.

Our staff has been active in a variety of endeavors outside of ESG this year. Professor King offered a new version of introductory physics (8.02x) in the regular curriculum this year which was based in part on the work he did last year with students in their ESG physics experiments. He was also one of four ESG staff members who participated in MIT's Interphase program this past summer. Professor Vandiver was involved in helping develop new plans for Interphase 1989 as well this spring. Ms. Sweet counseled graduate student women part time and co-led two support groups for 18 graduate student women under the auspices of the Graduate School Office. She also participated in her third year as an interviewer for Professor Benson Snyder's Freshman Interview Project.

We will continue to explore new ways of teaching academic subjects at ESG for the coming year. Under the direction of Professor Ingram, we plan to offer a tutorial version of 7.01 General Biology in the spring. We are also investigating the possibility of initiating self-paced tutorials for 1.00 Introduction to Computers and Engineering Problem Solving for the same term. We are excited about the new 24 unit course in physics and philosophy we are offering and hope that it might expand beyond our program if successful. We welcome Professor Ingram into our program and look forward to continuing to utilize ESG's small size and interactive format as a springboard for curricular innovation.

HOLLY B. SWEET
J. KIM VANDIVER

George Russell Harrison Spectroscopy Laboratory

The George Russell Harrison Spectroscopy Laboratory is engaged in research in the field of modern optics and spectroscopy for the purpose of furthering fundamental knowledge of atoms and molecules and pursuing advanced engineering and biomedical applications. Techniques include the use of lasers and modern optics, microcomputers and other data acquisition systems.

The Laboratory is directed by Professor Michael S. Feld of the Department of Physics. Professor Jeffrey I. Steinfeld of the Department of Chemistry and Dr. Ramachandra R. Dasari, Principal Research Scientist in the Laboratory, are Assistant Directors.

An Interdepartmental Laboratory, the Spectroscopy Laboratory encourages participation and collaboration among researchers in various disciplines of science and engineering. Research contributors this past year were from several MIT departments, including Chemistry, Physics, Biology, Electrical Engineering and Computer Science, Mechanical Engineering and Applied Biological Sciences. There were also numerous collaborations with outside academic institutions, many of an interdisciplinary nature, as well as with government, industrial and medical organizations.

This past year was one of continued growth. The CW Raman Laboratory was updated with two ion lasers and an optical multi-channel analyzer. Two pulsed dye lasers were added to the pulsed UV/Visible Laboratory. In addition, a new laboratory for studying the physical and chemical basis of ablation of biological tissue became operational. Finally, the Laser Biophysics Laboratory was equipped with a high resolution inverted microscope capable of studying fluorescence from cellular and sub-cellular structures.

PERSONNEL

Three new staff members were appointed, Drs. Richard P. Rava, G. Sargent Janes and Irving Itzkan. In addition, Professors William F. Dalby of the University of British Columbia Physics Department and Charles H. Holbrow of the Colgate University Physics Department were appointed visiting faculty, and Dr. Paola Taroni from the Istituto di Fisica del Politecnico of Milan was appointed as a Visiting Scientist. Carter Kittrell left to join the staff of the Rice University Chemistry Department. Finally, on April 29 Professor Richard C. Lord died in Milton, Massachusetts. Professor Lord, a distinguished molecular spectroscopist, directed the Spectroscopy Laboratory from 1946 through 1976, a fruitful period which saw tremendous growth in the areas of infrared analytical techniques and development and utilization of large gratings for studying electronic spectra of atoms and molecules, and the initiation of laser spectroscopy in the Laboratory. Dr. Lord's gentle nature and quiet dignity earned the respect and affection of a wide circle of friends and colleagues. We will miss him.

MIT LASER RESEARCH CENTER

The MIT Laser Research Center (LRC), a National Science Foundation Regional Instrumentation Facility housed in the Spectroscopy Laboratory, is now in its ninth year of operation. The LRC enables researchers from

academic, industrial and other types of institutions to pursue research in broad areas of laser spectroscopy and dynamics, to develop new types of coherent sources and techniques, and to perform diagnostic studies of various substances and materials. Its unique facilities, which include a broad range of lasers and ancillary equipment, constitute one of the largest and best-equipped centers in the United States devoted to spectroscopic research. They are made available free of charge to qualified scientists and engineers from MIT and outside organizations.

MIT LASER BIOMEDICAL RESEARCH CENTER

The MIT Laser Biomedical Research Center (LBRC) is now in its fourth year of operation as a Biotechnology Resource Center of the National Institutes of Health. Biomedical applications of lasers and laser spectroscopy promise to change the face of medicine as it is currently practiced. The LBRC's charter is to develop the scientific understanding required for advanced clinical applications of lasers. LBRC activities can be grouped into four categories: Laser ablation and propagation of light in tissue; spectroscopic properties of cells and tissue; laser spectroscopic imaging; and laser welding and mediation of the healing process. In addition to core research, collaborative and outside research projects are conducted at the Center. Resources of the Center are provided free of charge, on a time-shared basis, to medical researchers who wish to pursue research in this important new field.

New laboratories and new equipment have been added to facilitate the programs of the two Centers. Currently, there are over 40 major laser systems. Equipment and facilities include continuous wave (CW) and pulsed dye lasers pumped by ion lasers, excimer lasers and Nd:YAG lasers; a tunable laser facility which provides intense pulses of light continuously tunable over the wavelength range 216-4500 nm; a picosecond dye laser facilities along with a single photon counting detection system; an infrared diode laser spectrometer tunable in the 3-30 μ m wavelength region; UV and visible resonance Raman facilities; equipment for performing spectrally resolved fluorescence microscopy and fluorescence lifetime studies; and computer interfaced absorption and fluorescence spectrophotometers. All laser systems are interfaced with microcomputers which control experiments and collect and analyze data. Auxiliary equipment includes a transient digitizer, fluorescence microscopes and several optical multichannel spectral detectors.

RESEARCH HIGHLIGHTS

Professor Steven R. Tannenbaum of the Department of Chemistry and the Division of Toxicology and Drs. Billy Day and Paul Skipper of the Division of Toxicology have continued their studies on fluorescence spectroscopy of protein and DNA adducts of chemical carcinogens in collaboration with Drs. Ramachandra R. Dasari and Mark M. Doxtader of the Spectroscopy Laboratory. Both synchronous scanning and fluorescence line narrowing (FLN) techniques have been investigated by application to oxidation products of polycyclic aromatic hydrocarbons (PAH) and to etheno adducts of DNA bases. Line narrowing of a variety of adducts has been achieved at low temperature and promises to greatly enhance the specificity and sensitivity of sample analysis. The combination of capillary gas chromatography-mass spectroscopy and FLN has the potential to identify PAH adducts isolated from human tissues in the subpicomole range, which is the amount actually present in many human populations.

Professor Steinfeld has been carrying out infrared double-resonance measurements on rotational and vibrational relaxation in spherical-top molecules, including methane ($^{13}\text{CD}_4$) and silane, using a pulsed CO_2 laser pump and a tunable diode laser probe. The most remarkable results obtained for these systems concern state specificity in rotationally inelastic collisions. Highly specific propensity rules operate in state-to-state rotational relaxation. There are particular "gateway" states coupling rotational manifolds through which the population flows preferentially. This result was quite unanticipated on the basis of bulk-averaged rotational relaxation measurements. These measurements are being extended to asymmetrically deuterated methane (CHD_3) and to ozone, with particular emphasis on understanding collision-broadening effects in the latter system.

Professors Robert W. Field and Robert J. Silbey, both of the Department of Chemistry, continue their collaboration with Professor Richard Redington of the Texas Tech University Chemistry Department in a study of H-atom tunneling in tropolone. High resolution, supersonic jet, fluorescence excitation spectra have been recorded for several isotopomers, allowing definitive vibrational assignment of all observed features. The effects of vibrational excitations localized on heavy atoms remote from the O-H...O tunneling center are enormous and mode-specific, and they are being used to construct a potential energy surface for this intramolecular H-atom transfer process. This research provides valuable insight into the large effects of remote atoms on the dynamics of internally hydrogen-bonded biomolecules. Analysis of the fluorescence excitation profiles obtained as a function of laser power show that in the S_1 state of tropolone fast nonradiative relaxation competes with photon absorption to excite a fluorescence and strongly predissociative higher electronic state.

Professors Field and Silbey continue their studies of the structure and dynamics of acetylene. Progress has been made in three areas. The acetylene-vinylidene isomerization is a prototype of the sort of 1,2-hydrogen shifts envisioned by organic chemists but hitherto inaccessible to high resolution spectroscopists. A combined group theoretical and double-resonance experimental approach has identified the spectroscopic signature of isomerization in spectra of acetylene at such high vibrational excitation (2 eV) that rotation-vibration spectra are intrinsically unassignable. Statistical measures of spectra, derived from nuclear physics and nonlinear (chaotic) dynamics, are providing new insights into intramolecular dynamics. Dr. Jean-Paul Pique, of the Laboratoire de Spectrometrie Physique (France), has suggested that a recurrence that appears in the Fourier Transform of spectra of 3 eV excited vibrational levels of acetylene is associated with H-orbiting CCH, a vibrational analog of electronic Rydberg states. Pique's conjecture is being tested by isotopic substitution studies. A new, predissociated electronic state of acetylene has been observed and characterized by Optical-Optical Double Resonance (OODR) Spectroscopy. OODR provides rotational resolution, which was critical to establishing the equilibrium structure, symmetry, and predissociation mechanism of this previously unknown state.

Professor Field has made significant progress in characterizing the electronic structure of gas phase transition metal monoxides (MO). Because of its simplicity relative to the other MO molecules, CaO is an instructive prototype. Spectroscopic evidence has been obtained for

zero-order features such as integer valence (e.g. $\text{Ca}^{2+}\text{O}^{2-}$ and Ca^+O^-) and localized electron (on Ca^+) - hole (on O^-) electronic structures. CaO is shown to be the simplest molecular example of an electron-hole pair and thereby illustrates the spectroscopic signature of electronic localization. Analyzed spectra of CaO provide an opportunity to deperturb the observable adiabatic, mixed-valence electronic states back to diabatic, integer valence, potential energy curves and an interaction energy. These zero-order integer valence quantities for CaO will provide insights into the mixed valence electronic structure of the other MO molecules. The ultimate goal of this approach is to reduce spectroscopically derived molecular properties to atomic properties which display periodicity and molecule-to-molecule transferability.

Professor Keith A. Nelson of the Department of Chemistry is carrying out nonresonant and resonant Raman spectroscopy of several condensed-phase materials. In collaboration with Dr. Douglas Hall of Corning Glass Works, he is examining several nonlinear optical glasses. The Raman spectra are useful in understanding the role of "local" vibrational motion in the femtosecond optical responses of the glasses. He is also examining photochemically reactive crystals and liquids in an effort to elucidate the reaction coordinates along which molecules move in the first few hundred femtoseconds after photoexcitation. The excimer-forming crystals pyrene and perylene, and the solution phase organometallics $\text{Cr}(\text{CO})_6$ and $\text{Mn}_2(\text{CO})_{10}$, are under investigation.

Professor Stephen J. Lippard of the Department of Chemistry is studying the Raman spectral features associated with oxo- and hydroxo bridged polyiron centers in a series of polyiron proteins and model compounds. Characterization of $\{\text{Fe}_2\text{O}\}^{4+}$, $\{\text{Fe}_4\text{O}_2\}^{8+}$, $\{\text{Fe}_6\text{O}_2(\text{OH})_2\}^{12+}$, $\{\text{Fe}_6\text{O}_2(\text{O}_2)\}^{12+}$ and $\{\text{Fe}_{16}\text{MO}_{10}(\text{OH})_{10}\}^{26+2}$, $\text{M} = \text{Mn}$ or Co , cores in newly synthesized biologically relevant model complexes is continuing. In addition, Dr. James Bentsen, also of the Department of Chemistry, is using newly acquired Ar^+ and Kr^+ lasers for the low temperature investigation of the formation of dinuclear iron centers in the proteins ribonucleotide reductase and methane monooxygenase. The latter work is being carried out in collaboration with Professor JoAnne Stubbe of the Chemistry Department. In addition, several studies of the binding of dioxygen to dinuclear iron cores of relevance to hemerythrin are being studied in conjunction with Dr. Bentsen and Dr. William A. Tolman of the Department of Chemistry.

Professor Mark S. Wrighton of the Department of Chemistry and his collaborators have been involved in studies of inter- and intramolecular excited state electron transfer. The objectives of the research include identifying factors influencing rates of forward and back electron transfer in multicomponent molecules. Systems under investigation include porphyrin-viologen and porphyrin-ferrocene molecules which have been synthesized in the Wrighton group. Techniques used in the studies include transient Raman and transient absorption spectroscopies.

Small surface flaws on metallic structures of aircraft and nuclear industries initiate and propagate cracks at much higher speed than ever thought. Such small surface flaws are reproducibly generated by MIT Fatigue Research Group and Nuclear Materials Group, led by Professors R.M.M. Pelloux and R.G. Ballinger of the Department of Materials Science and Engineering, using Nd:YAG solid state laser of the Spectroscopy Laboratory. Two projects have been carried out during the last year.

The first one is focused on nickle-base superalloys for jet-engine turbine application. The crack growth rate starting from the laser-induced flaw is experimentally determined for various loading conditions.

Professors Pelloux and Ballinger's second project is aiming at the development of a sensitive technique to detect small flaws on metal surfaces. It has been shown that a high frequency AC Potential Drop (ACPD) technique can be used together with reduced probe spacing with the help of laser induced crack initiation. A detection sensitivity of 50 μm or smaller cracks is expected with a probe spacing of 1 mm. Once the ACPD technique is calibrated, it is the only sensitive method of small crack detection which is applicable to hostile environments such as nuclear power plants where both temperature and pressure are too high to apply any sophisticated electronic transducers with similar sensitivity.

The tensile strength of interfaces between micron thick protective SiC coatings and C fibers are of fundamental interest in the development of tough and damage resistant composite materials. An experiment is being developed by Professor Ali S. Argon of the Department of Mechanical Engineering in which this strength can be measured by laser spallation. In this technique, a laser pulse of about nanosecond duration and sufficiently high amplitude is converted into a narrow pressure pulse by absorption in a thin opaque layer sandwiched between a quartz plate and the back surface of the substrate containing the coating. Upon reflection from the front surface containing the SiC coating, the pressure pulse will become tensile at the interface and spall off the coating if the stress amplitude is large enough. Scoping experiments have demonstrated that SiC coatings of 1-2 μm thickness can be spalled off readily in this manner, and experiments with piezo electric crystals have established that the profiles of the stress pulses can be accurately characterized. Experiments are now in progress on the actual measurements of interface strengths.

Professors Forbes Dewey of Mechanical Engineering and August Witt of Materials Science are investigating the use of new crystal structures to produce nonlinear optical effects. This program, sponsored by the U.S. Navy, has succeeded in using the rotational twin defects in CdTe and other similar crystals to enhance the production of second-harmonic radiation from CO₂ lasers. Applications of this technique could be valuable to wavelength-tunable laser spectroscopy sources, to laser communication transmitters, and to multi-wavelength atmospheric probes. Experiments are continuing on testing the optical properties of crystals grown by Professor Witt and Dr. Piotr Becla, a principal member of the team.

Professor Toyochi Tanaka and Dr. Sridhar Gorti, both of the Department of Physics, have been involved in the observation of molecular Brownian motions within single live cells, in situ, by making use of microscope laser light scattering spectroscopy. In their studies emphasis has been placed on elucidating the mechanisms associated with laser-tissue interaction and primary bile secretion at the cellular level. In particular, the effects of laser irradiation on hemoglobin (Hb) at a laser output wavelength of 577nm have been determined in terms of Hb diffusivity within single red blood cells exposed to different dose irradiance. The results of these experiments evidenced a threshold

laser dosage at which Hb denaturation occurred. The data obtained may well establish new guidelines for the treatment of portwine stain disease by the technique of selective photothermolysis. The physical-chemical state of primary bile secreted within the canalicular space of isolated rat hepatocyte couplets was studied in order to gain further insight into the nature of human gall stone formation. Several physiologic and pathologic agents were used to determine the rate of primary bile secretion under cholertic and cholestatic conditions. Unlike studies involved in determining the physical-chemical state of distal ductal bile, the study of primary bile secretion had evidenced changes in biliary lipid aggregates at the cellular level and literally "at the moment of birth" of bile.

Professor David Pritchard of the Department of Physics and his colleagues have obtained the first radio frequency spectra from atoms confined in a magnetic trap. These spectra were diagnostic of the sodium atoms' energy distribution, and showed that they were a hot (by our standards), 90 millikelvin. After laser cooling (using a Doppler technique), the atoms in the trap were cooled to about 2 mK and had sufficient density ($>10^9/\text{cm}^3$) to absorb -85% of the probe laser on its passage through the sample. Next year members of this group hope to develop some novel ideas they have for cooling to microkelvin temperatures.

Professor Daniel Kleppner of the Department of Physics has been studying the onset of chaos in a small quantum system. There has been a resurgence of interest in classical dynamics stimulated by a growing appreciation for the role of nonlinear phenomena and the development of new techniques for handling nonlinear problems. The onset of disorderly motion- chaos - is of particular interest. The manifestations of chaos in quantum mechanical systems is of fundamental concern in this area. Classical motion is recognized to be a special case of quantum behavior, but quantum mechanics does not appear to have much in common with disorderly motion. Extensive numerical experiments have been carried out but experiments on real systems are lacking. Experiments have now been carried out on a real physical system: a highly excited atom in a magnetic field. Because of its relative simplicity, this system has come to be regarded as a paradigm for studying quantum and classical chaos. It has been discovered that the spectrum of the atom contains orderly progressions in a regime where the classical motion is chaotic, a finding contrary to the accepted notion of how quantum systems behave. In addition, the experimental results point the way to accurate quantum theoretical solutions to a key problem in atomic physics: the behavior of a simple system which lacks an underlying symmetry.

Professor Feld and Drs. Dasari, Michael Otteson and J. Timothy Hutton, all of the Spectroscopy Laboratory, continue their research in laser-induced nuclear orientation (LINO), which has been successfully applied in a table top experiment to measure the laser-induced anisotropy in the gamma ray decay distribution of short-lived ($1\mu\text{s}$) ^{85}Rb atoms. Recent experiments have succeeded in obtaining sub-Doppler resolution anisotropy signals for the first time, which allows us to measure the nuclear quadrupole moment of ^{85}Rb . Secondly, the investigators hope to use this technique to measure the angular correlation between the moments of the electron and anti-neutrino emitted in the beta-decay ^{85}Kr - ^{85}Rb . In addition, they are currently investigating the feasibility of performing these experiments on-line at a reactor or accelerator

facility, which should greatly expand the number of nuclear systems to which this technique is applicable.

Professor Feld and Dr. Richard P. Rava of the Spectroscopy Laboratory are engaged in biomedical research using laser induced fluorescence to diagnose disease in human tissue. Fluorescence contour mapping is being utilized to understand the emission of tissue in terms of individual fluorophores in the tissue, and to choose the optimal excitation wavelengths for diagnosing disease. Fluorescence spectra from individual tissue components using a fluorescence microscope have been measured, and permit an understanding of the emission on a morphological level. Modeling the tissue using this information has allowed for diagnostic algorithms which have a sensitivity of over 90% for detecting disease in artery wall, colon and urinary bladder. In collaboration with colleagues at the Cleveland Clinic Foundation, laser-induced fluorescence and the diagnostic algorithms are being utilized in a clinical setting to detect disease in artery and colon.

Professor Feld, Dr. Irving Itzkan, Dr. G. Sargent Janes and their colleagues are continuing experiments to understand the mechanisms governing laser ablation of tissue for microsurgery and various percutaneous applications. In particular, schemes for the effective removal of hard tissue, such as calcified atherosclerotic plaque, are being examined. Experiments such as temperature measurements of the hard tissue ablation process and fluorescence measurements during ablation are being utilized to understand the mechanism of ablation. In parallel with this work and in collaboration with colleagues at the Cleveland Clinic Foundation, a clinical system is being developed for diagnosing and treating atherosclerosis using laser light delivered percutaneously through optical fibers.

Professor Feld and Dr. Firooz Partovi of the Spectroscopy Laboratory have introduced new refinements in the theory of thermal laser ablation and have justified the use of steady-state solutions in the transient case of pulsed ablation. They have also developed computer simulation models to study fluorescence and the distribution of laser light within multilayered tissue.

Professor Feld, Dr. Dasari and Dr. Young Park, also of the Spectroscopy Laboratory, initiated studies of laser-induced fluorescence in the time domain with picosecond lasers. Fluorescence decay behavior of normal and plaque artery has been studied to establish tissue diagnosis in time domain. The results show that fluorescence decay can be used to identify tissue type.

Professor Feld, Dr. Hutton and his colleagues are continuing experiments to study the interaction of single atoms in an open optical resonator. Results include enhancement and suppression of spontaneous emission, as well as observation of radiative level shifts of a visible atomic resonance line. Results of experiments with an optical cavity having higher finesse show larger line width enhancement, suppression and level shifts than was observed in previous experiments. In addition, recent experiments have revealed low lying atom-cavity dressed states, showing evidence for energy exchange between atom and resonator mode, a system which can be viewed as two fundamental damped coupled quantum oscillators. Such results have led to measurement of the atom-cavity coupling constant (sometimes referred to as the vacuum Rabi frequency).

470 School of Science

Future experiments will include further study of atom-cavity coupling effects as well as onset of stimulated emission effects. This work is part of a long-term program to study superradiance and other coherent radiative processes in an optical resonator.

MICHAEL S. FELD

Laboratory for Nuclear Science

The Laboratory for Nuclear Science (LNS) provides support for research by faculty and research staff members primarily in the fields of basic nuclear and elementary particle physics, including the activities of the Center for Theoretical Physics and the Bates Linear Accelerator Center in Middleton, Mass. In addition, it provides a computing facility and an electronics design and development facility for its programs. The primary experimental programs are in three areas. The largest local effort is in intermediate energy nuclear physics, at the Bates Linear Accelerator Center in Middleton, Massachusetts. There is a users group in relativistic heavy ion physics with activities at Brookhaven National Laboratory (BNL). The Laboratory also has a users' group at the Los Alamos Meson Physics Facility (LAMPF) and at the Paul Scherrer Institute (PSI) in Switzerland. In high energy physics, there are major projects in the US at Fermi National Accelerator (FNAL) in Batavia, Illinois; and the Stanford Linear Accelerator Center (SLAC) in Palo Alto, California; and abroad at the European Center for Nuclear Research (CERN) in Geneva, Switzerland; and at the Gran Sasso Laboratory in Italy.

Experimental High Energy Physics

Electromagnetic Interactions Group (EMI)

The Electromagnetic Interactions Group (EMI) led by Professor Samuel C.C. Ting is concentrating its efforts and resources in completing the installation and debugging procedures of the L3 detector at the LEP accelerator at CERN (European Council for Nuclear Research), Geneva, Switzerland. As in the past twenty years, the EMI group continues to bear the leading responsibility for the design, construction, assembly, execution and data analysis of its experiments. The L3 Experiment represents one of the largest international collaborations in the history of science.

The purpose of the L3 experiment is to study photons, electrons and muons very precisely and deepen our understanding of subnuclear phenomena, especially the origin of masses of elementary particles. In the technical design of this experiment every effort has been made to ensure that the resolution of detecting photons, leptons, and hadron jets is optimized. Technical specifications, as stated in the L3 Technical Proposal (May 1983), have been followed and design values have been met or exceeded. Specifically the L3 detector has been designed to achieve the following:

1. The measurement of photons, electrons and muons with a resolution of 1% at 50-100 GeV momentum.
2. Measurement of hadron jet energies with a good resolution together with photons and leptons.
3. A large magnetic hall with $BL^2 = 160 \text{ kg-m}^2$ so that the central part of the detector can be easily modified or removed, making this experiment readily adaptable for future phases of LEP.

The L3 Experiment is distinct from the other LEP and SLC detectors and therefore provides the opportunity to explore and understand unique physics phenomena. In addition to the unprecedented scale and standard of precision of the L3 detector, a strict timetable has been followed by L3 in order to be operational by the first physics run of LEP scheduled for mid July 1989. LEP expects to reach an energy level of 50 GeV per beam in Phase I and later in Phase II to reach an energy level of 100 GeV per beam.

Collaborating with the MIT/LNS/EMI group on the L3 experiment is an international consortium of physicists, engineers and students from 38 different institutes and from 13 countries. It is the first large-scale high energy physics experiment in which scientists from the United States, the Soviet Union, Western Europe and the People's Republic of China work together with the strong

support of their respective governments. The experiment is expected to go into operation this summer.

UA1 Experiment

The UA1 group is studying proton-antiproton collisions at the CERN Sp \bar{p} S Collider in Geneva, Switzerland. The physicists in UA1 are investigating many exciting phenomena in particle physics. After its discovery of the W^{\pm} and Z^0 particle, the intermediate vector bosons predicted by the standard electroweak model, this group made a detailed analysis of the properties of these particles and of their production mechanism. One of the many results of this study was an upper limit on the number of light neutrino species in the universe (<6). The analysis of the production of heavy quarks (charm and beauty) led to the first observation of mixing between B^0 and \bar{B}^0 mesons; such mixing has only been observed so far in the $K^0 - \bar{K}^0$ system.

A search for other fundamental particles such as a sixth quark (top), a heavy lepton and various supersymmetric particles is taking place. This group is also presently building a position detector to be installed in the new Uranium-TM/P (tetramethylpentane) calorimeter which is in preparation. With the commissioning of the new antiproton accumulator (ACOL) the luminosity, hence the rate of data-taking, increased by a factor of 10. The new optics (micro β) prepared at the interaction region will give another factor of two improvement in collision rate. With the new detector installed next year, UA1 will conduct a new study of proton-antiproton collisions with high statistics and this measuring precision -- one of the main physics objectives is a precise measurement of the $W - Z$ (weak bosons) mass differences to search for indication of physics beyond the standard model.

The Accelerator Physics Collaboration

The Accelerator Physics Collaboration (APC) group is conducting experimental research at Fermi National Accelerator Laboratory (FNAL) in Illinois and the Gran Sasso (GSL) at L'Aquila, Italy.

The group has recently taken data at FNAL in the world's highest energy neutrino beam, utilizing a holographic bubble chamber. This experiment is investigating a new domain in neutrino physics. An M.I.T. graduate student (who's Ph.D. has now been awarded) has studied the hadron fragmentation function in this new energy regime and has reported clear scaling violations at this high energy. The experiment in GSL, which is the world's largest underground laboratory, will study particle physics and astrophysics problems. The main structure for the experiment (designed at M.I.T.) is now installed. It is planned to have the first detector modules in place by January 1, 1990. The American group is responsible for the data acquisition hardware and software. This work is on schedule and the current plans are to start shipping the hardware to GSL early this fall. This experiment will study 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 experiment in Gran Sasso Laboratory, which is the world's largest underground laboratory, will study particle physics problems and astrophysics problems. The particle physics problems are related to new radiation coming from Cygnus X-3. These studies might prove that Cygnus X-3 is a quark star which is emitting a new form of matter not yet seen on earth. In addition, this experiment can make the best measurement on the neutrino oscillation problem. From the point of view of astrophysics, the detector will study the production of solar neutrinos by the sun, the yearly rate of collapsing stars in the universe and possibly point out sources emitting high energy neutrinos. Since this experiment is an order of magnitude larger than previous type experiments, the probability is high that new phenomena will be found.

The Counter Spark Chamber Group

The Counter Spark Chamber (CSC) Group has been involved in a FNAL-based program of studying the structure of the nucleon and the structure of the weak interaction using neutrinos as a probe. The major focus has been on the analysis of the data obtained to determine the structure functions of the nucleon, as sensed by the weak neutral current, and to make detailed comparisons of the neutral and charged current interactions with the nucleon. The results obtained are consistent with the predictions based on the Weinberg-Salam-Glashow (W-S-G) weak electromagnetic unification theory and the quark-parton model, and have yielded a new precision value of the weak mixing angle. The group has continued its neutrino studies with Tevatron II, the FNAL 1000 GeV accelerator. We have completed the final experimental run in this program and are now analyzing the data. A measurement of the strange quark component in the nucleon quark-anti quark seen from this data gives the result that the strange quark occurs about half as frequently as ordinary up and down quarks.

In addition, the group participates in two other major collaborative programs. (1) The use of μ mesons at the Tevatron to study nucleon structure and the mechanisms of particle production. The Group has participated in the construction of a spectrometer to be used in these studies. The first data has been obtained with this system and it is now under analysis. (2) The use of 50 GeV e^+e^- colliding linac beams (Stanford Linear Collider) at the Stanford Linear Accelerator Center (SLAC) to investigate the physics of the intermediate vector boson Z^0 . The Group is collaborating in the construction of an advanced detector, called the SLAC Large Detector (SLD), which will exploit the new energy region to investigate a number of physics issues. In particular, they will search for the Higgs particles produced in the decay of the Z^0 . The SLD program is the major group effort for the foreseeable future. The detector is now being assembled and the new accelerator is now yielding about 10-20 Z^0 /day.

Lepton Quark Studies (LOS)

The LOS group is continuing its collaboration on the SLD experiment, which is to be performed with the Stanford Linear Collider (SLC) at the Stanford Linear Accelerator Center (SLAC). The group is participating in the final construction phases of the Central Drift Chamber. Tracking data from this drift chamber is to be used in conjunction with calorimeter and vertex detector information, allowing for the identification of various charged particles. This identification is crucial in the search for the fundamental Higgs boson and in establishing the possible existence of new composite particles such as heavy-quark mesons and new gauge-like bosons. It is also crucial in the study of Z-boson decays to test the limits of the present gauge theory. The detector is scheduled for completion near the end of 1989 and it is hoped that data will be taken in mid 1990.

Experimental Nuclear Physics

Relativistic Heavy-Ion Physics (HI)

The Heavy-Ion Group is actively engaged in the study of collisions of nuclei at very high energies (15 GeV per nucleon) and speeds, essentially the speed of light. The goal of these measurements is the study of matter at energy and baryon densities almost an order of magnitude greater than normal nuclear matter. New phases of nuclear matter may also appear in such collisions. In these dense states a plasma may be formed from the quarks which make up the nuclei and the gluons which bind the quarks. It is to these studies that the heavy-ion group is now committed, including about eight graduate students some of whom could form the core personnel in this new field.

The studies of these phenomena have begun with beams of 400 GeV silicon nuclei produced at Brookhaven National Laboratory. The Heavy-Ion Group has designed and constructed high

performance drift chambers which constitute the tracking component of a large solid angle spectrometer. This spectrometer has made the first measurements of particle cross sections from high energy nucleus-nucleus collisions. One very surprising result is the large relative increase in the K^+/π^+ ratio in nucleus-nucleus collisions to that in nucleon-nucleon collisions. The origin of this increase is not yet understood, but could result from the production of strange quarks in a hot and dense hadron gas. A second generation experiment is now in the planning stage with a member of the group as co-spokesman.

Neither the energy nor the mass of these initial beams is expected to be high enough to produce a quark-gluon plasma, but the conditions will still be an order of magnitude more extreme than any hitherto observed under controlled conditions. But, by 1992 we will be accelerating nuclei as heavy as gold. With this beam, we may be able to reach far enough into the extremes of mass and density, extremes which approximate those that are conjectured to have occurred in the early stages of the expanding universe.

Intermediate Energy Nuclear Physics

The principle activity in this field is centered at the Bates Linear Accelerator Center, which is operated under the joint auspices of LNS and the U. S. Department of Energy. The Laboratory serves the national community, providing intermediate energy electron and photon beams for precision studies of nuclear structure and for reaction studies aiming at fundamental understanding of the nuclear force. The intermediate energy research programs of MIT faculty and research staff, both at Bates and at off-campus facilities, are described below; Bates developments are described in a separate contribution.

About twenty-five MIT graduate students were associated with the intermediate energy research program during the past year. A recent graduate, Elizabeth Beise, was awarded the Demos Prize, given annually for doctoral research and outstanding contributions at the Bates Laboratory.

A large fraction of the intermediate energy faculty and senior research staff carried out, at Bates in 1987 to 1988, a difficult experiment aimed at the first complete characterization of the electromagnetic structure of the deuteron, the most elementary nucleus. The difficulty arose from the need to perform a double scattering measurement so as to measure the spin orientation of the struck deuteron. This experiment will bear directly upon the issue of identifying the operative degrees of freedom in strongly interacting matter at the 10^{-13} cm length scale. Lengthy analysis is nearly complete.

Several new initiatives concerned with spin measurement are being pursued actively. For example, a "high density" polarized helium gas target is being developed. Several interesting applications are envisioned, based upon the property that polarized ^3He offers the chance to study neutron properties. The target was tested successfully with high current beams. The first experiment is planned for the coming year.

A major effort has been and will continue to be focused on studying nuclear response to large energy transfer. A benchmark coincidence study of protons knocked out of the nucleus by electrons is underway. The goals of the program include understanding single-nucleon motion in the nucleus, modifications of nuclear structure in the medium, and contributions to the electromagnetic current arising from the close interaction of two (or more) nucleons. In the last year, a very large yield of high energy deuterons was discovered. This may lead to important insights into nuclear clustering, but a definitive study awaits the high duty factor capability now being developed. Direct emission of single protons by intermediate energy photons has been studied over the last several years. An interesting scaling phenomenon has been found in comparing data for different energies and may provide the clue needed for extracting information about the probability for finding nucleons with very large momentum in the

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nucleus. This in turn would be very instructive for understanding the short-distance structure of the nucleus. A difficult experiment examining the same process with neutron emission was carried out. The results are surprising in showing that the neutron cross section is larger than that for protons.

A unique test of the unified theory of electromagnetic and weak interactions has been performed at Bates. The experiment aims to measure the very small asymmetry expected ($\sim 10^{-6}$) in elastic scattering of right- and left-handed electrons from nuclei. The data are now being analyzed; a statistical uncertainty of about 1.5×10^{-7} is expected. This will pave the way for an ambitious second generation program aimed at testing the Standard Model and studying nucleon flavor structure. In addition, we envision a robust program of polarized electron studies aimed at strong interaction physics (i.e., nuclear structure and reactions).

Complementary to the Bates experiments are investigations by the MIT groups at other accelerator facilities. The largest program is that examining selected pion-induced reactions at the Los Alamos Meson Physics Facility. This program aims at isolating pion interactions with nucleons and with nucleon clusters in the nuclear medium, particularly in the energy regime corresponding to the lowest excitation of the nucleon. In doing so, one expects to learn how internal nucleon structure affects the strong interaction of baryons. Double charge exchange studies are isolating the pion interaction with nucleon pairs. Recent coincidence results on single charge exchange point to shortcomings in our previous characterization of baryon-nucleon interactions. A new initiative in the study of pion annihilation has been taken; a large acceptance detector has been built for use at the Paul Scherrer Institute (PSI). The first experiment will take place late this year.

Design of a solar neutrino detector, called BOREX, utilizing nuclear neutrino interactions is progressing in collaboration with groups at AT&T Bell Laboratories, Milan University (Italy), Argonne National Laboratory, and others.

Bates Linear Accelerator Center

The William H. Bates Linear Accelerator Center, located in Middleton, Massachusetts and operated under the joint auspices of the MIT Laboratory for Nuclear Science and the US Department of Energy, serves as the national user facility for intermediate energy electro-nuclear physics. The Laboratory supplies high intensity (average current ~ 50 microamps), high quality electron and photon beams with energies up to one GeV. A spectrometer of unmatched resolution supports a program of precision measurements of nuclear electromagnetic charge, current, and magnetization distributions. A second experimental area is equipped to support a vigorous program of photoreaction studies, with protons, neutrons, charged and neutral mesons, and photons detected with good resolution. Further, the electron beam duty factor of - one percent, together with a unique set of magnetic spectrometers, permits an exploratory program of coincidence studies. This program has been particularly compelling in pointing towards a major facility upgrade needed for effectively pursuing new directions in the field; this upgrade will be described below. Beam time is assigned to experimental proposals on the basis of scientific merit with the advice of a Program Advisory Committee with international representation. Roughly one-third of the beam time is presently assigned to MIT faculty and staff. There are currently about 200 active participants in the research program, drawn from over 50 universities and research laboratories; this substantial number reflects the unique capabilities developed at Bates. The MIT-Bates intermediate energy research program has been exceptionally effective in graduate education, producing between five and ten percent of the nation's Ph.D.'s in experimental nuclear physics during the last several years.

The Center is committed to an ambitious program of studies on few-body nuclei. These are of fundamental interest in our attempts to understand strong interaction dynamics at distance scales smaller than the size of the nucleon. Specifically, an extremely complex (double-scattering) experiment has been performed, providing the first measurement of the monopole and quadrupole charge distributions of the deuteron in a theoretically interesting regime. Several upgrades and equipment fabrications were needed to give us this unique capability. In addition, studies of deuteron breakup under extreme conditions (i.e., the proton and neutron unbound but moving off together) will be extended to very small distances. This process has provided the most convincing and quantitative evidence for the role of pions in the nuclear ground state. To push this understanding to the much shorter distance scale of considerable current interest, we will need to develop the capability for measuring cross sections two orders of magnitude smaller than those which have been measured so far. Both of these deuteron experiments involve large collaborations and several institutions. Other experiments on the deuteron and proton will require the design and construction of out-of-plane spectrometers; these are being built as an MIT-Illinois collaboration.

The research program in another experimental area centers on studies of nuclear response to large energy transfer, i.e., energies large enough to produce mesons and to produce internal excitation of the nucleon. For example, the only measurements of elastic photon scattering from a nucleus above the threshold for pion production have been performed at Bates by a Boston University-MIT group. These data have complemented pion scattering studies from other laboratories in yielding a quantitative characterization of the nuclear interactions of excited nucleons. The best available theory of these interactions has been confirmed. New results from Bates are now coming forward in the production of charged pions, including coincidence studies. These will further test our ideas about hadronic interactions.

An important exploratory coincidence program, in which high energy protons knocked out of the nucleus are measured simultaneously with the scattered electron, is being pursued by scientists from MIT, William and Mary, Maryland, Argonne, California State, and other institutions. These have been benchmark studies pointing to an understanding of how the nucleus absorbs large momentum and energy transfer. Recent results include a direct measure of the mean free path for nucleon propagation in the nuclear medium and insight into the role of multinucleon currents at high frequency. The momentum transfer independence of the cross section has confirmed the basic integrity of nucleons inside the nucleus. Recently, a surprisingly large yield of high energy deuterons was found, suggesting an important program of correlation studies. The much more extensive experimental study demanded by these results argues strongly for the proposed Bates upgrade to high duty factor operation.

A collaboration led by Yale, MIT and Syracuse performed an experiment testing the unified theory of electromagnetic and weak interactions. The experiment measures the very small asymmetry expected ($\sim 10^{-6}$) in the elastic scattering of electrons with spin aligned parallel or antiparallel to the beam direction. The data are now being analyzed; a statistical uncertainty of 1.5×10^{-7} is expected. We are now starting a major program of strong interaction studies with the polarized beam. This will be a unique program, essentially using spin observables for the first time in electronuclear physics. A second generation parity program is now under discussion.

We have begun construction of the South Hall Ring (SHR) which, upon completion, will provide two crucial new capabilities: CW (continuous wave) extracted beams and an internal target capability. The internal target program will allow the study of heavily ionizing recoils in coincidence and, most importantly, will provide the first full spin capability in our field. We hope that these unique capabilities will be available for research in 1992. The conventional construction is well along and will be completed during the next year. Installation of technical

components will start in spring 1990. The development of new detectors matched to the vastly upgraded accelerator capabilities will start in earnest during the next year.

E. J. Moniz

The Center for Theoretical Physics

Particle Theory

This has been a very active year, with members of the group making marked progress and becoming involved in lively controversies. Research ranges from questions of interpretation of recent and proposed experiments using the well-established standard model, through cosmological conjecture, to exploration of the beautiful connections between quantum field theory and geometry.

Recent measurement by the European Muon Collaboration of deep inelastic scattering of polarized muons from protons has triggered a theoretical debate over the structure of the spin content of the proton. Members of the group have been in the forefront of this controversy. There is still much to be learned here, and a program of measurements of basic quark matrix elements has been suggested. The prospect of deep inelastic scattering measurements with polarized nuclear targets has stimulated theoretical analysis and the discovery of new structure functions which would measure the gluon content of a nucleus not associated with individual protons and neutrons.

The question of the role of different types of cosmic strings in the evolution of the universe involves fascinating problems of particle physics and astrophysics. The dynamics of a network of cosmic strings in the early universe has been the subject of a sophisticated computer simulation. Preliminary results are very promising. A subject of keen controversy in early universe physics has been the process which produced the observed excess of baryons over antibaryons. It has been claimed that standard model field theory provides a process which would wash away any baryon asymmetry produced in the very early universe. Members of the group have analyzed the situation and repudiate this claim.

To go right back to the beginning of the universe it is necessary to understand quantum gravity. Detailed research has been carried out on the process of production of a whole new universe by quantum tunnelling. This is an attempt to explore simultaneously the basis of the theory and the tools available to calculate the consequences, in a regime where even the fundamental concepts (like time) are subject to controversy.

Though the hope of a few years ago that the theory of superstrings would serve as a fundamental theory has faded somewhat, members of the group have made remarkable progress towards the construction of a field theory of interacting closed strings. The structure required is extremely elaborate but also in a sense very natural. The elegant subject of conformal field theory, an offshoot of progress in string theory and in statistical mechanics, has seen much technical advance.

Further proof, if any was needed, of the deep and beautiful connections between quantum field theory and modern geometry, has been found. Three dimensional topological field theories, which members of the group played a large part in inventing and studying, have been shown to have remarkable properties of great interest in both physics and mathematics.

Nuclear Theory

Nuclear theorists address a broad range of problems in contemporary nuclear physics, combining 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 physics and the role of QCD effects in nuclei is a growing focus of research, both because of its fundamental significance and the unique resources at the interface between nuclear and particle physics in the Center for Theoretical Physics. Because QCD is presently intractable analytically, our research addresses hadronic physics from a number of complementary viewpoints which focus on different aspects of the problem. One major effort is to calculate the properties of the nucleon numerically in lattice gauge theory in order to test and distinguish between the various contemporary quark, bag, and soliton models. Studies of QCD and confinement explore the role of color deformed states, the formal similarity to Anderson localization, the quantum mechanics of a multiply connected space, the ground state wave functional of pure Yang-Mills theory, many-body techniques appropriate to large N_c , and classical Yang-Mills solutions. The role of antisymmetry in modifying the quark momentum distribution in the nucleus has been demonstrated and QCD in two space-time dimensions has been used to test techniques and approximations for four dimensions. Chiral models have been used to study radiative decay of hyperon resonances, to elucidate the spin content of the proton, and to explore the strange quark content in the proton.

Relativistic heavy ion collisions comprise another area of growing activity, motivated by the unique opportunity they provide for fundamental exploration of new regimes of matter, new data from Brookhaven and CERN, and the experimental effort in this field at MIT. A flux tube model has been developed in which two interpenetrating nuclei become color charged and generate a strong confined color field which creates quark-antiquark pairs. In this model, the hydrodynamic evolution of the plasma, the non-Abelian classical evolution of the color fields, hadronization of the flux tube, and stopping power have been investigated. Subsequent to the suggestion from this group that J/ψ production could reflect screening in the quark gluon plasma, such suppression was observed in the CERN experiments. Quantitative calculations of the transverse momentum dependence of J/ψ suppression are consistent with the CERN data, and the role of dynamic Debye screening in the plasma and final state interactions in a deconfined phase have been investigated.

Nuclear many-body theory provides the foundation for many aspects of nuclear theory, and has thus been an area of continuing interest. Problems in the quantum theory of collective motion ranging from fission to the quantization of large amplitude vibrations involve periodic solutions to time-dependent mean-field theory. Thus recent efforts have focused on understanding the nature of periodic solutions to multidimensional classical systems, their implications for quantum chaos and calculating periodic solutions for physical processes. A coherent state representation has been shown to provide a useful bridge between periodic classical solutions and quantum eigenstates. Stochastic techniques have been applied to a variety of nuclear many-body problems ranging from lattice gauge theory to the exact solution of non-relativistic models with static interactions. A new stochastic method for Fermions in any spatial dimension has been developed which circumvents the long-standing problem associated with antisymmetry.

Electromagnetic interactions have been a continuing focus of theoretical interest, both because of the unique precision of electromagnetic probes and important new questions in coincidence experiments and polarization observables arising from the Bates program and South Hall Ring project. An important development in the study of polarization observables was the discovery of

new structure functions for deep inelastic scattering from polarized nuclei. A new formulation of quasielastic electron scattering yields an exactly calculable expression for the corrections to impulse approximation and thus allows quantitative extraction of the nuclear momentum distribution. Other topics include the study of sub-nuclear degrees of freedom in elastic scattering from the deuteron, understanding the nuclear response function and Coulomb sum rule in inclusive inelastic scattering, the study of isospin mixing in parity violation experiments, and investigation of photon and neutrino reactions. Analysis of hadron-hadron scattering using R-matrix theory and the bag model has been used to investigate exotic multi-quark resonances. Activities in intermediate energy physics also include the study of the pion optical potential, pion nucleus scattering, and pion production.

Part of the vitality of the Center for Theoretical Physics arises from broad interests in general problems in theoretical physics. Thus, the nuclear theory group has also addressed such topics as QED in strong fields and finite chemical potential, general lattice field theory, quantum spin systems, and problems in nuclear astrophysics.

J. Goldstone

Summary of Support

Participants in the various research programs during the past year amounted to approximately 390 people. This includes 47 academic staff members, 90 graduate students, and at least 30 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 80 research staff members with Ph.D.'s including visitors and guests, and 140 employees in supporting categories such as engineers, technicians, machinists, computing and administrative personnel. At least fifteen Ph.D.'s, and two B.S.'s were awarded based on thesis research within LNS.

Support during fiscal year 1989 from the contract with the US Department of Energy (DOE) is expected to total \$26,266,000. This sum breaks down as follows: Operations costs (salaries, wages, materials, services, travel, and overhead) were \$17,358,000, of this \$5,753,000 was for experimental and theoretical high energy physics, \$9,713,000 was for intermediate nuclear energy physics for the support of the Bates Linac Facility and research program both at Bates and elsewhere, and \$1,892,000 was for nuclear structure theory, solar neutrino, and for heavy ion experiments. Equipment costs are expected to total \$7,808,000; of this, \$6,558,000 will be for High Energy physics and \$1,250,000 for medium energy and heavy ion physics. A total of \$1,100,000 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 \$126,500.

A. K. Kerman

George R. Wallace, Jr., Astrophysical Observatory

The George R. Wallace, Jr. Astrophysical Observatory is a teaching and research observatory located in Westford, Massachusetts. Its facilities consist of a 24-inch reflecting telescope, a 16-inch reflecting telescope, several 8- and 14-inch telescopes, a 5 1/2-inch astrograph, and a small building that houses a workshop, darkroom, and observers' quarters.

Several upgrades to observatory facilities occurred this year. Dr. Edward Dunham and Stephen McDonald (Class of 1989) completed the installation and alignment of the 5:1 optical reduction system for the 24-inch telescope, which was built by Byron Williams (Class of 1988). This system increases the area of sky covered by a CCD frame by a factor of 25.

A major goal of the observatory is to implement high-speed communications to the main campus, so that observations can be carried out remotely, with complete control of the telescope and instruments. This would also allow CCD images on the campus network (immediately after recording), where they would be accessible to students through Project Athena workstations. To this end, Dr. Dunham, Stephen McDonald, and Leslie Young upgraded the SNAPSHOT camera software to work between computers on an Ethernet, and Richard Baron (grad) arranged for the installation of an optical fiber data link between Wallace Observatory and Haystack Observatory. Hopfully the link between Haystack and the MIT campus will be completed soon.

Last fall 63 students in 12S23 Observing the Stars and Planets and 8.287J-12.117J Observational Techniques of Optical Astronomy, used the observatory for their laboratory work. In the spring, 25 students from 12S23 also used the observatory facilities.

Observing programs included testing the upgraded SNAPSHOT camera and the inception of CCD astrometric observations of Pluto stellar occultation candidate stars by Dr. Dunham and Stephen McDonald. Astrometric and photometric observations, in support of observing programs with the Hubble Space Telescope were begun by Amanda Bosh (grad), Andrew Rivkin (Class of 1991), and Andrea Thompson (Class of 1991).

JAMES L. ELLIOT

VICE PRESIDENT, EQUAL OPPORTUNITY OFFICER, AND SECRETARY OF THE CORPORATION

FIVE-YEAR PLANNING

This summer marks the fifth anniversary of MIT's first formal five-year plan, prepared in 1984-85 by the then-Provost, Professor Francis E. Low. All senior officers of MIT submitted five-year plans for their respective areas, and have updated these plans in one form or another on the occasion of the annual budget cycle.

The areas for which I am responsible include some 640 people in seven administrative departments and several staff services within the Office of the President and the Corporation Office. In the summer of 1981, the Vice President's Staff Group (made up of department managers and senior staff in my areas) developed our own custom version of a strategic planning and management approach which was adapted in 1984 to fit the planning process across MIT. Five years ago, I reviewed in these pages our statement of mission and appended an outline of our organization, our strategic plans, and our principal objectives.

I thought it would be useful this year to highlight, in these prefatory remarks to the departmental reports, some of the major changes and accomplishments of the past five years, and to update the list of our principal agenda (see Appendix).

EQUAL OPPORTUNITY

The current workforce at MIT is 14 percent minority (seven percent Asian American, five percent Black American, and two percent Hispanic American) and 86 percent non-minority, 38 percent female and 62 percent male. These statistics have not changed over the past year.

Last year, I reported extensively on the affirmative action record, both within our areas and MIT-wide. There is very little I can add to the frustration which my associate, Clarence G. Williams, and I feel when it comes to MIT's recruiting and hiring of underrepresented faculty members. Of the 47 appointments made in a 12-month period, only one was an underrepresented minority. This experience is typical of the past five years.

The Equal Opportunity Committee (EOC) has spent much of its meeting time talking about the problem of the paucity of the pools in science and engineering, as well as the difficulty in attracting blacks and Hispanics to academic careers, and to the Boston area where housing costs are exorbitant.

The EOC members believe awareness of both the critical needs and of methods to meet these needs must be raised higher among faculty members in order to foster initiatives and sustained support for MIT's institutional commitment. The EOC will report to the faculty this fall.

In discussions with the Provost, the EOC prepared a draft of a proposal for MIT to spearhead a new program, in concert with a few sister universities, aimed to provide special incentive fellowships for minorities who enter graduate school in science or engineering fields with an intention to pursue an academic career. The Provost is optimistic that private foundations will respond positively to our request for substantial funding for this program.

In the academic and administrative staff within my own areas, the progress has been spotty, with modest improvement. As I noted last year, there is no problem in the employment numbers of women and in the hiring and promotion of women to management positions. In the Vice President's Staff Group, three of the nine directors and six out of the eight senior staff are women. Within each of our seven departments, women outnumber men in management roles. Women occupy 57 percent of the 372 total positions in the academic and administrative staff in our areas. Out of these 372 staff members, however, only 22 (or 6 percent) are black or Hispanic minorities. Last year we hired 38 individuals in administrative staff positions: 21 of them are women (55 percent) and four are underrepresented minorities (11 percent). The fact that our hiring rate for minorities is higher than our total representation is promising, but it is a record we can and must improve.

PEOPLE, PROGRESS, AND PERSPECTIVE

Two major organizational changes occurred in our areas in 1985: First, reporting responsibility for Student Affairs was transferred from our area to the newly appointed Associate Provost for Educational Programs and Policy. Second, I was elected Secretary of the MIT Corporation in the fall of that year and reorganized the Office of the Secretary. Elizabeth J. Whittaker serves now as Associate Secretary of the Corporation, and Lois A. Graham is Assistant to the Secretary, with primary responsibility for the operation of the Corporation's 24 Visiting Committees.

Other developments include a substantial turnover in our leadership group. The Vice President's Staff Group (VPSG) included 14 persons in 1984. Excluding myself and our Senior Staff Assistant, Kimberly N. Bagni, who joined our office three years ago, the VPSG now consists of 17 persons: nine managers and eight staff members. Since 1984, six of the nine managers are new to their current responsibilities -- half through internal promotion and half from outside MIT, and six of the eight staff members are new to the Vice President's Staff Group -- four through internal promotion or transfer within MIT and two from outside.

The new directors include Joan F. Rice (Personnel, 1984); Michael C. Behnke (Admissions, 1985); Arnold N. Weinberg, M.D., and Linda L. Rounds (Medical Director and Medical Department Executive Director, both 1986); Kathryn W. Lombardi (promoted to Director of Public Relations Services, 1988); and Kenneth D. Campbell (News Office Director within Public Relations, 1986). The new staff members of the VPSG include Clarence G. Williams (Assistant Equal Opportunity Officer, 1984), Laura B. Mersky (Associate, Analytical Studies and Planning Group, 1986), Maureen C. Wolfe (Personnel Officer, 1987), and Meses. Whittaker (1985) and Graham (1987), already mentioned in the reorganization of the Office of the Secretary of the Corporation. Stephen D. Scarano joined our group in 1986 in the new position of Assistant to the Vice President, for Information Systems.

In addition to these changes in management personnel over the past five years, there were significant changes in MIT policies and programs, spearheaded both by the new managers and staff and by those of us who have continued in our posts over a longer period.

Leading the pack of these program changes (in terms of magnitude and impact on everyone who is employed at MIT) is the design and implementation of a unified retirement plan. As part of a broad strategic review of all MIT benefits, the new pension program drew on the creative and collaborative efforts of many MIT staff, consultants, senior officers, and, most centrally, on our Benefits Manager in Personnel, Deborah A. Kelley (herself a newcomer to

MIT), and her able colleagues. Joan F. Rice, the Director of Personnel; Kerry B. Wilson, Assistant Director of Personnel for Compensation; and our full-time consultant, Edward W. Powers, played key roles in the arduous process of planning and designing the new plan.

The unified plan goes into effect on July 1, 1989, in record time of less than two years from its initial inception.

On the student side, a new Admissions publication program received national recognition two years ago; a significant increase of 20 percent in applications occurred in that same period; and the enrollment of underrepresented minorities in the Freshman Class reached a record high of 17 percent last fall, thanks to extraordinary efforts of the Admissions staff. This year the national demographic trends have caught up with us. Overall applications for the Freshman Class declined 10 percent, reflecting the overall decline of the high school cohort. Happily, the quality standards of the applicants to MIT have held strong.

There were some concerns, however, voiced by faculty members about the preparation and the interest level of entering students in math and science. To address these concerns, a major study of admissions policy was undertaken by the Faculty Committee on Undergraduate Admissions and Financial Aid. The Committee, chaired by Professor Keith D. Stolzenbach, should be commended for its thorough and painstaking review and analysis of statistical information and faculty opinion. The Committee's Report was presented to the faculty last May. Reactions and discussion are sure to continue into next year.

Serving both students and the entire MIT community, the Medical Department engaged in two very significant outreach efforts: First, under the guidance of the new Medical Director, an intensive program of student health education was launched by Mark A. Goldstein, M.D., Chief of Student Health Services; and Janet H. VanNess, Director of Health Education Programs. Second, under the aegis of the new Executive Director; Dr. John Christian Kryder, Assistant Medical Director for Operations and Planning; and the Medical Management Board, a new flexible health insurance option was introduced to the MIT Community last year. This option combines the advantages of full, in-house care (traditionally provided by the MIT Health Plan) with the flexibility for patients -- under a higher deductible option -- to choose, on their own, physicians outside of the panel of MIT doctors or MIT referrals. The new program has been received well in the MIT community where individual flexibility of choice, some skepticism about comprehensive care, and demand for understanding, as well as for quality of service, are hallmark characteristics.

Last year, in my report, I noted the enormous public relations value that accrued to MIT from the historic flight of Daedalus, the human-powered vehicle designed by MIT faculty, students, and alumni. Last fall, MIT's decision to enter NCAA Division III Football captured national media attention! The Director of Athletics and his staff and the 40 student athletes who signed up for the new varsity sport were deluged by attention from the press and from Network television in ways that would be the envy of Division I superstars. Neither our Athletic Department nor our public relations staff were used to such instant notoriety. We are used to having an athletic program that is unique in its breadth and participation, however; and MIT is wholly deserving of one more form of public recognition, as a place where high quality and extraordinary effort are to be expected in all that we do.

Last spring the MIT Press published *Made in America: Regaining the Productive Edge*, a report of an MIT study on United States productivity conducted over the past two years by 16 faculty members, commissioned by the President and the Provost under the chairmanship of

Professor Michael D. Dertouzos. The Commission's work received widespread recognition and publicity, and the Press has already sold 30,000 copies of the book. This publishing project, incidentally, was moved from manuscript to the bookstores in less than four months.

Turning now from public acclaim to internal efficiency and improvement of our work processes, each of the offices in our group made significant strides forward toward automation of records and work procedures in the past five years. The publications group in Public Relations has undertaken desktop publishing programs for major reports and on-line management of the information for the MIT bulletin; Career Services, Admissions, Athletics, the News Office, the Equal Opportunity Office, and the Corporation Office have each moved forward in some form of computer-aided administrative systems. The Medical Department, which pioneered with a local area network six years ago, has made significant progress to improve the functioning of that system. The Personnel Office completed a full-scale business analysis of its operation and is now searching for the most suitable human resource system available in the market in order to replace the home-grown system that has seen better days. In all of these efforts on information systems development and improvement, Stephen D. Scarano, Assistant to the Vice President, for Information Systems, has been a steady voice of advice, wisdom, and experience.

Looking ahead, I have appended to this section the list of principal planning agenda and priorities for our areas, for fiscal year 1990 and beyond. On the whole, both the achievements of the past five years and our unfinished agenda underscore, as they have in the past, the enormous importance of imaginative leadership, personal talent, and outright hard work required of all who are involved in serving this institution. Charles Kettering once said, "The harder I work, the luckier I get"! For all of us, it was a very busy and productive year. Next year we will hit the jackpot.

CONSTANTINE B. SIMONIDES

APPENDIX

MISSION, PRIORITIES, AND AGENDA

VICE PRESIDENT, EQUAL OPPORTUNITY OFFICER, AND SECRETARY OF THE CORPORATION

I. Mission

The mission of the group of offices and services for which I am responsible has not changed significantly in the past years. In essence, it is a dual goal of policy development and the provision of human services:

Mission (Organization and Stewardship of Human Resources):

To support the institutional mission of MIT in education, research, and public service by developing and implementing effective policies for equal opportunity and for governance -- including the organization of the Corporation and its visiting committees -- and by providing efficient services for all MIT people -- students, faculty, staff at all levels of employment, and trustees.

II. Priorities and Agenda

Our work for the next year and beyond will continue to revolve around four major thrusts:

- Complete benefits review and restructuring; act on recommendations of the Committee on Family and Work;
- Strengthen information systems, analysis, communications and supervisory training;
- Launch Building on Diversity program(s), aimed at using the recognition and valuing of differences in order to improve effectiveness, productivity, and teamwork; and
- Maintain aggressive public relations.

In greater detail, the agenda, as they relate to the departments that report to me, may be summarized as follows:

1. Decide on personnel information systems and begin to implement.
2. Address faculty concerns about Admissions without losing momentum on recruiting of minorities and women and on the quality or breadth of the applicant pool.
3. Step up Admissions-related studies and research.
4. Launch Building on Diversity program: pilot groups within CBS areas in 1989. Purpose: To build on personal differences as bridges toward greater productivity and teamwork. Evaluate pilot and, if successful, broaden program.

5. Evaluate equal opportunity decentralization policy implemented in 1986.
6. Continue aggressive health education outreach to student community.
7. Emphasize quality of managed health care with flexible options.
8. Improve geographic coverage of health services to campus families and to Lincoln Laboratory personnel and families.
9. Raise funds for athletic facilities -- both short- and long-term.
10. Decide future athletic faculty status and rectify departmental personnel structure.
11. Improve analysis and reporting on legal services in order to control expense and avoid excessive use of counsel.
12. Improve record keeping: Complete Corporation meeting index; begin index of Executive Committee records.
13. Continue emphasis on promotional and general communications to enhance public understanding of science, to improve MIT's public image, and to support the Campaign for the future.
14. Step up development of computer-based publications and information systems in order to provide more timely, accessible, and cost-effective communications for the MIT community and the public.
15. Strengthen intellectual and fiscal independence of MIT publishing.
16. Emphasize performance appraisals and training of supervisors.
17. Improve teamwork and communication throughout our areas and across MIT.

Office of Admissions

Much time and attention was focused on supporting the study of admissions conducted by the Committee on Undergraduate Admissions and Financial Aid (CUAFA), in communication with others about that study, and in modifying our selection procedures to reflect emerging faculty opinion. The final report makes a number of recommendations, which I will summarize here:

- 1) Admissions decisions should place greater weight on demonstrated capability in MIT's traditional strengths of mathematics and science and in particular on a strong commitment to these disciplines.
- 2) Applicants with genuinely extensive intellectual range should be highly valued and sought after.
- 3) Non-academic activities, talents, and personal qualities should be considered mostly as a means of distinguishing among individuals of comparable academic ability.
- 4) There is social and educational value in considering issues of access and diversity in making admissions decisions.
- 5) Efforts to increase and sustain the number of women and minority students at MIT should continue. No changes are called for in the admissions procedures for women and under-represented minorities.
- 6) The fundamental operational aspects of current admissions procedures are working well and should be retained.
- 7) Faculty should be more involved in the admissions process at MIT.
- 8) There should be institutional encouragement and support for coordinated educational studies.

With respect to the admissions cycle itself, demographic realities appear to have finally affected MIT and most other highly selective institutions. Our decline in applications of 10% was close to an average of declines at comparable institutions. Interestingly, MIT and many other institutions experienced no decline in the number of highly qualified applicants. A similar phenomenon may occur next year. There is an even larger decline in the number of high school seniors but more of them scored very well on the 1988-89 Preliminary Scholastic Aptitude Test. These fluctuations make for uncertainty in such areas as ordering the correct number of publications and in predicting the yield of accepted applicants.

The number of women in high school who express an interest in science and engineering continues to fall at a greater rate than that of men. We were consequently pleased that applications of women to MIT fell at the same rate as that of men and that women once again comprise over one-third of the entering class.

Applications from Black students also fell by 10%, but there was no decline in applications from other minority groups. Consequently, we were delighted to enroll the second highest number and percentage of under-represented minority students in MIT's history (154,14.6%). We also enrolled 254 Asian American students, an increase of 73 over last year.

Another focus of time and attention during 1988/89 was a thorough functional analysis of the Admission Office. This analysis resulted in many recommendations for changes in structure and procedures. Many changes were instituted this year, and the analysis will serve as a guideline for more changes in the future.

MICHAEL C. BEHNKE

ADMISSIONS TRENDS 1980 - 89

	<u>1980</u>	<u>1981</u>	<u>1982</u>	<u>1983</u>	<u>1984</u>	<u>1985</u>	<u>1986</u>	<u>1987</u>	<u>1988</u>	<u>1989</u>
<u>Entrants from Secondary Schools</u>										
Preliminary applications	11,223	12,526	12,525	12,653	12,465	14,698	14,349	16,237	17,408	17,832
Final applications	5,677	5,922	5,921	5,959	6,055	5,747	6,213	7,372	7,437	6,698
Admissions offered	1,809	1,909	1,911	1,818	1,854	1,885	1,762	1,826	1,833	2,018
Actual registration to date	1,081	1,030	1,109	1,082	1,059	1,061	1,001	1,012	1,003	1,073*
Registrations as percent of admissions	59.7%	54.0%	57.5%	61.1%	57.1%	56.2%	57.0%	55.4%	54.7%	53.2%
Number of secondary schools represented	894	835	842	891	722	860	830	848	844	867
Percent of students from 9 northeastern states	47.8%	51.9%	51.0%	50.5%	50.5%	44.7%	43.5%	39.8%	36.4%	32.5%
<u>College Transfers</u>										
Total applications	1,131	818	1,378	1,024	1,048	909	890	870	905	617
Applications completed	471	399	425	400	304	295	317	304	349	296
Admissions offered	167	93	118	128	124	131	137	106	141	90
Actual registrations	119	76	82	91	91	101	97	80	94	**
Registration as percent of admissions	71%	82%	69%	71%	73%	77%	71%	69%	69%	--
<u>Graduate Students</u>										
Total applications	7,832	9,075	9,342	8,836	7,922	8,032	8,564	8,443	8,863	8,655
Admissions offered	2,380	2,926	2,920	3,007	2,223	2,467	2,457	2,243	2,101	2,549
Actual registrations	1,212	1,465	1,476	1,542	1,290	1,338	1,105	1,019	1,104	1,437
Registration as percent of admissions	51%	50%	51%	51%	58%	54%	49%	45%	53%	56%

*Some of these will drop off over the summer (around 20-25)

** As of 1 week after mailing admit letters, there are 35 enrolling.

Educational Council

Over 1650 alumni/ae served as Educational Counselors this past year, representing MIT in all 50 states, the District of Columbia, Puerto Rico, The Virgin Islands, and 47 foreign countries. This group included 280 women and 66 minorities (46 Blacks, 7 Puerto Ricans, and 13 Mexican-Americans). The Educational Counselors represented MIT at 257 local College Fair programs; they conducted approximately 6600 admissions interviews, and held countless conversations with prospective MIT students and with local school personnel. Of all MIT applicants, 94.8 percent (98.2 percent within the United States) were interviewed by a local Educational Counselor.

Project Contact is a program which puts current undergraduates in touch with applicants, Educational Counselors, and school personnel. This past year 495 students, representing 130 different geographic areas (including 9 foreign countries), participated in this program run by the Educational Council Office.

Meetings for newly admitted students were held in 46 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. Local Educational Council members assisted members of the Admissions staff in arranging for 104 Central Meetings in 91 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 86 volunteers, all women professionals (from AMITA, SWE, AWIS, AWM, or other women's professional organizations) to visit 42 high schools throughout the Greater Boston Metropolitan Area. They spread the word to young women (and in some cases young men) about the importance of continuing to study math and science in order to keep career options open. A High School Visiting Program was run in Los Angeles as a joint effort with Cal Tech.

The MIT admissions videotape was requested by 43 High Schools to make copies.

A new system of rating EC reports was instituted which enabled each Educational Counselor to be rated on the usefulness of the interview report. Feedback from the EC's indicates that our alumni greatly appreciate the quantitative evaluation of their work.

BONNY S. KELLERMANN

Department of Athletics

I. Overview

In many ways this year has been a major test of the strength and fiber of our Department as we managed to achieve significant success with participation levels and competitive results in the face of constant cost-cutting, the uncertainty of future department faculty status, the unexpected distractions of first year Division III Football, and the most demanding year of external ECAC and NCAA responsibilities in the career of the Director. I believe we are a Department built on a firm foundation of talented people and mutual respect with a philosophy of collaboration and a structure of operating procedures that, for the most part, withstands uncertainty and crisis in order to best serve our constituencies.

In this regard I want to make special mention of the consistently effective contributions of our various support staff groups - all dedicated and hardworking in fulfilling their responsibilities and always thoughtful and supportive in their working relationships both within the Department and with our user constituencies. Particular thanks and praise go to our versatile and flexible clerical support group and coordinator Sandra Lett; our tireless equipment and sports medicine groups and coordinator Paul Grace; and our reliable athletic utility and pool attendant groups coordinated by William Malone and John Benedict, respectively. Our instructors, coaches, and senior administrators hold these invaluable colleagues in our debt.

II. Highlights of the 1988-89 Year

- 1) Under Assistant Director Francis O'Brien's leadership, Intercollegiate success this year included several programs enjoying their greatest number of victories and/or highest NCAA place finish in many years. Consistent with such team achievement, four MIT coaches were named regional coach of the year - a record for MIT. MIT students were named All-American as a team player or national event placer some 42 times (actually 21 athletes in 9 different sports) which is also a new high for such student athletic honors.
- 2) MIT, as a member of the Eastern Collegiate Football Conference, participated in a NCAA Football game for the first time in history. Athletic Director Royce Flippin is the first commissioner of the conference. The resultant publicity was unexpected and positive, as television, radio, and newspapers from throughout the country wanted a piece of the MIT football story.
- 3) Physical Plant, with Assistant Director Roderick Arthur, successfully completed the Alumni Pool renovations to redress the space inequities for women and improve women's access to the newly refurbished squash courts.
- 4) Physical Education total registrations of 7,680, with 3,341 for non-credit, are both all-time high levels, reflecting the relevance and increasing interest in the varied 53-course offerings offered by Directors Gordon Kelly, Candace Royer, and their instructor colleagues.
- 5) We have initiated the planning for a new pilot course for freshmen to provide a comprehensive overview of the physiological, psychological, and social components of wellness for a healthy and happy life. The pilot will be offered in September, 1989. Kimberly O'Brien and Timothy Walsh are the co-coordinators for our Department. The Medical Department is a co-sponsor for planning and instruction.

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6) The planning groundwork has been completed by Francis O'Brien and our colleagues from sister institutions for a new men's intercollegiate conference in the sports of basketball, baseball, cross country, golf, soccer, and tennis to include, initially, Babson, Coast Guard, MIT, Norwich, WPI, and Western New England College. The first competition in selected sports will commence with the 1990-91 academic year, Director Royce Flippin serving as assistant commissioner. It is anticipated that this conference will provide MIT students with a more meaningful competitive experience in a balanced and controlled grouping with championship opportunities and post season honors. Expansion of the league is planned for the immediate future with private universities in the New England area.

7) Women's intercollegiate track and lacrosse took significant steps towards varsity NCAA status, with sharply increased participation levels and enhanced coaching leadership. We are continuing to support these trends, with the possibility of formal elevation to varsity NCAA status in the coming year.

8) Physical Plant, with Roderick Arthur, has completed the realignment of the Dupont second floor athletic and exercise rooms. We have essentially swapped the fencing room and general exercise room to bring the fencing room up to intercollegiate standards and provide greater space expansion flexibility for both wrestling and fencing, with the general exercise room now located in the middle, separating the two intercollegiate arenas.

III. Areas for Future Action

1) Phase III - Completion of a full review/update of the 1975 Phase III Athletic Facilities Plan. This will be presented to the 1990 Visiting Committee for discussion and approval, including issues of uncoupling a second pool and linking funding requirements to the MIT Campaign for the Future.

2) Athletic Field Situation - The Department of Athletics and Physical Plant are in full agreement that the large expanse of MIT athletic playing fields has deteriorated over time to a serious situation of unplayable conditions and concern for student safety.

The primary reason for this is the shifting and sinking of the land-fill mass that created the athletic field area in the first place. Our baseball outfield looks like a wavy sea. Rocks, cans, and glass seep through the grass on both our soccer fields. Steinbrenner field and surrounding track both have depression areas as a result of the sinking.

Athletics and Physical Plant are united in a plea for a major dollar and planning commitment by MIT to level and grade our entire athletic field complex, excluding the Omni Barry Field. Without a commitment of such magnitude, ongoing patchwork field maintenance is ineffective, demoralizing, and wasteful in both time and expense. And the losers are our students who participate in intercollegiates, intramurals, and general recreation.

IV. Personnel Changes

I want to make special mention of valued colleagues who have left our Department during the year or will not return in 1989-90. They will be missed:

Kristine Sullivan, Clerical Support, to Bank of Boston
Clair Tucker, Clerical Support, relocated to Seattle
Thomas Perry, Part-time Rifle Coach replaced by Dick Dyer
Louise Jandura, Part-time Field Hockey Coach replaced by Carol Martin
Jose Rivera, Assistant Trainer on leave of absence replaced by Ronald Laham

Finally, we are grateful for the recent addition of Laura Capone who has served two different functions in a short time and, with the many clerical changes, has settled effectively as my cheerful and supportive clerical support colleague.

ROYCE N. FLIPPIN, JR.

FIVE-YEAR LONG-TERM STRATEGIC OBJECTIVES

FUNDAMENTAL MISSION

To provide an adaptive, high quality, student-oriented physical education, recreation, and athletic program that emphasizes participation, competition, confidence, and leadership. To enhance the MIT human environment for the entire MIT community.

LONG RANGE (FIVE-YEAR) OBJECTIVE

- Recruit and hire quality people. Review and evaluate on a regular basis the development of professional skills and personal/career paths. Improve minority faculty/staff representation.
- Continue to carefully manage and selectively adjust offerings for one of the largest percent participation programs in the United States in intramurals, club offerings, intercollegiate teams, and general recreation opportunities; adapt to changing student body profile (more women; less men; more graduate students - both in total and housed on campus).
- Continue to reevaluate the relevance and quality of physical education programs in the MIT educational context and the student community. This will include support and develop of timely wellness/health fitness programs and gradual expansion of campus-wide health fitness individual testing and education programs; encourage joint projects with Medical Department.
- Develop external resources for improvement of existing facilities. Plan and promote implementation of Phase III new facilities, artificial field surfaces, and needed renovations.
- Resolve the deteriorating Athletic Field situation; continue to press for the Athletic Department consolidation of all inside and outside maintenance and building services associated with athletic programs.
- Support and sustain effective cost containment policies and procedures for control of all budgetary and operating accounts. Seek avenues that create more leeway in the annual operating budget.
- Sustain a close relationship with Admissions in the ongoing quest for highest quality students.

**CURRENT PROGRAM PRIORITIES
(Through FY 1989-90)**

1. Resolve discussions regarding the future of the Athletic Department faculty structure/tenure policy.
2. Complete review/updating of 1975 Phase III Athletic Facilities Modernization Program to include:
(a)future program priorities, (b)demographic trends, (c)future facility options and uncoupling priorities. Complete for February, 1990 Visiting Committee for determination of linkage to future funding options and priorities of MIT Campaign for the Future.
3. Incorporate the recently launched Safety Policy Review in a set of systematic safety procedures for constant supervision and periodic updating with respect to all athletic facilities and programs.
4. Consolidate cost containment systems and procedures to further improve operating efficiencies and pare operating expenses for annual balanced budgets.
5. Identify, recruit, and hire minority faculty/staff.
6. Continue to seek a solution for the equitable transfer of a portion of the Physical Plant Field Maintenance Staff to the Department of Athletics.
7. Introduce into the Physical Education course offerings a pilot program for freshmen that provides a comprehensive overview of the physiological, psychological, and social components of "Wellness For a Healthy and Happy Life."

EXHIBIT I

MIT ATHLETIC PROGRAM PARTICIPATION

	Report Year <u>1988-1989</u>	<u>1987-88</u>	<u>1986-87</u>
STUDENT ENROLLMENT (October Figures - Includes Specials)			
Undergrad Women	1,412	1,384	1,295
Undergrad Men	<u>2,913</u>	<u>2,993</u>	<u>3,148</u>
TOTAL	4,325	4,377	4,443
Graduate Women	1,017	1,005	1,045
Graduate Men	<u>4,158</u>	<u>4,183</u>	<u>4,268</u>
TOTAL	<u>5,175</u>	<u>5,188</u>	<u>5,313</u>
GRAND TOTAL STUDENTS	9,500	9,565	9,756
<hr/>			
STUDENT PARTICIPATIONS (Includes Multiple Activity Duplication)			
1. <u>PHYSICAL EDUCATION</u>			
Total Registration	7,680	7,482	7,004
(Undergrad)	(5,886)	(5,918)	(5,672)
(Grad)	(1,209)	(1,098)	(940)
(Staff)	(585)	(466)	(392)
2. <u>INTRAMURALS (M/W & COED)</u>			
Programs	18	21	22
Teams	928	1,030	1,015
Students (CUM)	9,498	10,581	10,129
3. <u>CLUBS</u>			
Programs	31	34	34
Students	707	831	1,076
4. <u>INTERCOLLEGIATES</u>			
<u>Women's Programs</u>	<u>13</u>	<u>13</u>	<u>12</u>
Student Participants	260	277	251
Varsity Letter Awards	148	134	135
<u>Men's Programs</u>	<u>24</u>	<u>24</u>	<u>24</u>
Student Participants	643	628	617
Varsity Letter Awards	314	340	317

EXHIBIT II

Physical Education Activities 1988-89
(In Order of Registration Volume)

<u>Activity</u>	<u>Reg. & Passed</u>	<u>Activity</u>	<u>Reg. & Passed</u>
Skating		Aquatics	
Beginner	561-321	Beginner	200-138
Hockey	171- 70	Adv. Beginner	122- 51
Figure	82- 40	Intermediate	15- 06
	<u>814-431</u>	Adv. Techniques	22- 04
Aerobics		Lifesaving I	15- 10
Aerobic Dance	485-118	Lifesaving II	12- 10
Low Impact	233-112	Diving	16- 04
Health Plan	81- 28	Scuba	38- 37
	<u>799-258</u>		<u>440-260</u>
Tennis		Volleyball	
Beginner	350-179	(Beg. & Int.)	370-188
Intermediate	282-151	Pistol	342-278
Advanced	79- 51	Sailing	341-176
	<u>711-381</u>	Yoga	328-136
		Squash	
		(Beg. & Int.)	302-142
		Exercise Fitness	301-302
		Table Tennis	197-117
		Fencing	173-104
		Archery	168-106
		Basketball	162- 89
		Sculling	156- 77
		Badminton	154- 97
		Skiing	149- 93
		Golf	94- 51
		Frisbee	89- 57
		Tai Chi	85- 23
		Lacrosse	
		Outdoor	54- 30
		Indoor	17- 08
			<u>71- 38</u>
		Judo	61- 38
		Karate	55- 29
		Rugby	35- 15
		Softball	34- 19
		Indoor Soccer	32- 17
		Rowing (Ex.)	30- 08
		Officiating	09- 06
		TOTAL	<u>7680-4038</u>

Register-Passed

EXHIBIT III
CLUB PROGRAMS PARTICIPATION 1988-89

	Report Year <u>1988-89</u>	<u>1987-88</u>	<u>1986-87</u>
Aikido	12	15	20
Archery	10	12	12
Badminton	30	30	33
Ballroom Dance	—	Removed	150
Bowling	Not Active	30	33
Cheerleading (Football)	14	14	12
Cheerleading (B'Ball)	10	Not Active	14
Crew (Grad Women)	10	16	24
Cycling	10	—	—
Cricket	Not Active	20	28
Dance Club	22	25	27
Fencing	32	33	35
Figure Skating Clubs	70	65	85
Folk Dance	—	30	42
Frisbee	25	25	66
Ice Hockey(Women)	35	30	32
Judo	15	10	Not Active
Karatedo Doshinkan	10	14	12
Korean Karate	25	25	31
Lacrosse (Women)	21	23	25
Outing (White Water)	20	20	21
Rifle/Pistol	45	45	53
Rugby (Men)	42	40	50
Rugby (Women)	21	20	14
Scuba	25	25	24
Shorinji Kempo	10	10	—
SKA Karate	12	25	30
Soccer (Grad Men)	41	35	28
Square Dance	—	Removed	25
Swimming (Masters)	30	35	32
Table Tennis	20	11	30
Tae Kwon Do	20	30	26
Water Polo (Women)	20	22	20
Water Polo (Men)	20	25	—
Wonhwa-Do	10	15	22
Wu-Tang (Boston)	Removed	15	14
Wu-Tang (MIT)	Removed	12	18
TOTAL PARTICIPANTS	707	831	1,076
TOTAL PROGRAMS	31	34	34

EXHIBIT IV

INTRAMURAL PARTICIPATION

Sport	1987-88		REPORT YEAR 1988-89	
	#Teams	Participation	#Teams	Participation
Badminton	40	200	38	190
Basketball	141	1128	125	1000
Cross Country	6	88	Inactive	-
Cycling	6	34	7	64
Fencing	4	19	3	24
Football	77	1155	63	945
Frisbee	52	520	36	432
Hockey	92	1104	104	1248
Octathon	16	240	16	240
Rugby 7's	12	84	14	98
Rugby 10's	12	120	Inactive	-
Soccer	80	1360	71	1207
Indoor Soccer	Inactive	-	-	-
Softball	134	1876	114	1596
Squash	25	125	24	96
Swimming	Inactive	-	-	-
Table Tennis	49	343	27	189
Team Tennis	31	124	48	192
Indoor Track	8	87	12	104
Triathlon	19	101	Inactive	-
Volleyball	181	1448	177	1496
Water Polo	39	390	34	340
Wrestling	6	35	8	37

21 Programs
1,030 Teams

10,581 Cumulative
Participants

87-88 Deleted: Indoor Soccer & Swimming
Added: Octathon

18 Programs
928 Teams

9,498 Cumulative
Participants

1988-89 Deleted:
Cross Country
Rugby 10's
Triathlon

EXHIBIT V

1988-89 M.I.T. INTERCOLLEGIATE WON-LOSS RESULTS

MEN'S SPORTS (24)				WOMEN'S SPORTS (13)			
	(A)				(A)		
FALL	W	L	T	FALL	W	L	T
Cross Country	0	4	0	Cross Country	7	1	0
Football	4	3	0	Field Hockey	7	8	1
Golf (B)	2	5	0	Soccer	3	12	0
Soccer	6	9	0	Tennis (B)	10	3	0
Tennis (B)	3	3	0	Volleyball	32	8	0
Water Polo	9	12	0				
WINTER				WINTER			
Basketball	14	8	0	Basketball	7	13	0
Fencing	10	8	0	Fencing	9	10	0
Gymnastics	4	2	0	Gymnastics	3	5	0
Ice Hockey	6	10	0	Skiing	23	27	0
Pistol	4	3	0	Swimming	5	4	0
Rifle	25	17	0				
Skiing	43	7	0				
Squash	11	14	0				
Swimming	2	4	0				
Track, Indoor	10	0	0				
Wrestling	11	5	0				
Volleyball	15	13	0				
SPRING				SPRING			
Baseball	17	13	0	Crew	3	5	0
Crew, Heavyweight	0	9	0	Softball	9	6	0
Crew, Lightweight	1	6	0	Tennis (B)	4	3	0
Golf (B)	11	4	0				
Lacrosse	6	7	0				
Tennis (B)	10	7	0				
Track, Outdoor	3	0	0				
1988-89 Totals	227	173	0 (.568)	1988-89 Totals	122	105	1 (.537)
vs. 1987-88	203	144	0 (.512)	vs. 1987-88	85	94	0 (.475)
Overall 1988-89 Totals 349 278 1 (.557)				vs. 1987-88 Totals 253 254 3 (.499)			

(A) No won-loss record for sailing
 (B) Golf and Tennis play a combined Fall/Spring schedule

Career Services and Preprofessional Advising

This was a year when the demand for scientists and engineers was broad rather than intense. Few industries were particularly hungry for talent - not surprisingly after six years of uninterrupted economic growth - but the number of employers with openings to fill made up for the lack of intensity. A total of 432 employers made recruiting visits, a near record. They included 413 companies and 19 government agencies. As in 1987-88, more than one in ten were financial houses and consulting firms interested in students with strong general skills rather than specific training.

The number of students having interviews was the highest ever, approximately 1830, compared with 1635 the year before. They included 1156 undergraduates, among them many interviewing for summer jobs; 420 candidates for master's and engineer degrees; and 250 doctoral candidates (an exceptionally high figure). Four postdoctorals (fewer than usual) rounded out the total. Because some large companies manage their own interview schedules we do not have an exact tally for the number of interviews taken, but we estimate the total at a little under 10,000.

The lack of intensity in the market was reflected in salary offers. In many disciplines starting salaries barely kept up with inflation. Thus, offers to bachelors rose 4.4 percent in mechanical engineering (to \$32,400), 3.2 percent in electrical engineering (to \$33,000), and 3.1 percent in computer science (to \$34,000). The highest percentage gains at the bachelor's level were in aeronautical and astronautical engineering (up 6.4 percent to \$31,900), chemical engineering (up 7.0 percent to \$34,000), materials science and engineering (up 7.8 percent to \$33,000), and management (up 6.4 percent to \$33,000). It is not clear that any of these high percentages reflect a surge in demand. There are special circumstances in each case. For example, offers to bachelors in aeronautical and astronautical engineering did not rise at all in 1987-88; there has been a shortfall of students in chemical engineering since the collapse in oil prices in 1982; and students in management have benefitted from the notoriously high salaries offered by Wall Street houses and leading management consulting firms.

In most disciplines offers at the master's level rose less than at the bachelor's level, and offers to PhDs rose even less. Thus, in electrical engineering offers to master's candidates rose only 2.6 percent (to \$40,000) and offers to PhDs rose a bare 1.0 percent (to \$55,000). In aeronautical and astronautical engineering offers to masters actually declined. The exception to this tale of offers declining with degree level is management. The Career Development Office at the Sloan School reports that the median offer to Sloan masters jumped ten percent.

The small rise in engineering starting salaries sits awkwardly with the argument made by many writers on America's industrial competitiveness that the country should graduate more engineers. It would seem that in the existing structure and culture of American industry the supply of engineers is in close approximation to employers' perceived needs.

Data from a questionnaire we gave to students graduating last June bear out the importance of the recruiting process to employers and students. The questionnaire was part of a project undertaken jointly by the Careers Office and the Development Office to help employers plan their recruiting at MIT to best effect. We targeted students who were taking jobs in industry. Seventy-one percent of the bachelors who responded, and 53 percent of the masters, reported that they had found their job through interviewing on campus. In the case of PhDs faculty were a more important contact (mentioned by 28 percent of the PhDs) but interviewing on campus (mentioned by 22 percent) was a close second.

The questionnaire threw light on the need of a company to sell itself. We make every effort to publicize employers' visits, printing and distributing up to 1,500 copies of a weekly recruiting flyer. We urge companies to give us an informative and persuasive description of themselves for the flyer because in most disciplines a student has many more recruiters to choose from than he can possibly see. Students told us that a company's description in the flyer was second only to its general reputation in persuading them to sign up for interviews. Other factors (a company's printed brochures, its product line, the advice of other students, etc.) were less important.

What sort of jobs are MIT students looking for in choosing companies to interview? The survey also provided some useful information on this. Engineering students reported that they were most interested in jobs in R&D (mentioned by 64 percent), followed by design (50 percent). Third in popularity, interestingly, was consulting (31 percent). Software and

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management information systems ranked fourth (20 percent). Manufacturing, on which many hopes are pinned these days, was mentioned by 18 percent of all engineers, by 44 percent of mechanical engineers, and by 1 percent of electrical engineers. Management students put business strategy and planning first (48 percent), followed closely by consulting (47 percent). Marketing ranked third (43 percent), ahead of financial services (35 percent). Manufacturing was mentioned by 16 percent.

The industry of most interest to both engineering and management students was "high tech". Seventy percent of the engineers and 52 percent of the managers said that it interested them "greatly". Consulting came second (40 percent and 43 percent respectively). Aerospace ranked third with engineers (24 percent); international business ranked third with management students (36 percent). New start-ups were in fourth place with both groups (22 percent of engineers, 33 percent of managers).

Members of the Development Office visited a number of companies during the summer who organize their recruiting especially well and used the pointers they gathered on these visits, and the data from the questionnaire survey, to draft a report, "The Corporate Recruiter's Guide to MIT". They discussed the draft with representatives from another forty companies who came recruiting in the spring and published the report in final form in June. The director of the Careers Office also drew on the survey to write an article for the College Placement Council's Journal on "Campus Recruiting in Changing Times". Both the report and the article were well received, eliciting a number of enquiries from

Another joint project was a symposium on minority recruiting which we organized for the Industrial Liaison Program. The topics covered ranged from the nation's changing demography to examples of the things employers and universities need to do to encourage a larger percentage of minority youth to pursue careers in science and engineering. Speakers from outside the Institute included Betty Vetter, executive director of the Commission on Professionals in Science and Technology; Lloyd L. Friend, III, R&D personnel and university relations director, AT&T Bell Laboratories (who described his company's support of minority programs from the high school level to the PhD); and Lewis E. Schumaker, college relations supervisor at DuPont (who laid out DuPont's minority recruiting strategies). Dr. Gray spoke eloquently at lunch on the scope of the commitment institutions need to make to increase the ratio of minority students and staff. The symposium was attended by about 130 representatives from ILP member companies who complimented us on the program. Word of the symposium has spread and several people who were not present have asked for a tape of r

Many students coming to the office want to find jobs where they can apply their humanistic skills and interests rather than technical skills they may be thought to have. They include students who have majored in the humanities or social sciences, but most are scientists and engineers who have come to realise that they are more discursive in their thinking, and less inclined to put their all into a technical problem, than their MIT peers. They often are shy about declaring themselves because they do not conform to the expected MIT pattern. They are a sort of liberal arts underground at the Institute.

Unfortunately they are inclined to think that the jobs described in our recruiting flyers represent the sum total of the job market. To reassure them that there are indeed other jobs out there we invited seven alumni who were members of the underground themselves to come back during IAP to talk about their spheres of work. We are grateful to all of them for giving a memorable series of talks: Alexander A. Bernhard '57 on law; Congressman Bruce A. Morrison '65 on government and public policy; Janice Marchiafava '88 on marketing and market research; Rafael Tallada-Valderas '88 on management consulting; Marc S. Miller '69 on journalism; Minto Bhandari '87 and Earl C. Yen '88 on financial services.

Medical School

Contrary to the national trend, the number of MIT applicants to medical school rose significantly, to 131, compared with 111 in 1987-88. A jump in the number of alumni applicants was responsible for all of the increase. The 83 undergraduates who applied, and the 5 graduate students, represented a decrease from the year before. The 43 alumni applicants were up from 16 in 1987-88. To date, 87 percent of the undergraduates have been accepted, 80 percent of the graduate students, and 74 percent of the alumni. Almost certainly more candidates will be accepted before schools open in the fall.

ROBERT K. WEATHERALL

Medical Department

The Medical Department has seen a variety of planning efforts come to fruition in programs providing expanded services, ready access, and high quality care for students and other members of the Massachusetts Institute of Technology (MIT) community. In addition, through the Environmental Medical Service (EMS), we have addressed health and safety issues outside of the Department, assuming responsibility for kitchen cleanliness and food safety and improved handling of biohazards and other wastes. Generated by a National Institutes of Health (NIH) mandate, we worked with MIT Administration and the Clinical Research Center (CRC) to bring the CRC into the Medical Department and to provide hospital care for CRC subjects requiring inpatient services. Student health and health education have been important continuing efforts through assignment of students to personal physicians, a Student Home (Living Unit) Health Service, broadened health education programs and a Health Education office in the Stratton Student Center.

Medical Care Activities

Dental Service: Dr. Cynthia Stevens, Chief

The number of patient encounters has continued to grow. With the arrival of the Delta Dental Insurance Plan many additional older patients, with a variety of dental diseases, have begun to be seen in increasing numbers. Prosthodontic and oral surgical care needs have increased among older patients. The service has been evaluating the activities of dental hygienists and assistants in providing efficient care and education in preventive activities for the population served.

The Medical Service: H. Walter Jones, Jr., Chief

Through retirements and resignations and the appointment of three new physicians, the Medical Service has undergone some changes. A series of meetings has served to examine present and future needs and to provide appropriate orientation and support for new staff members. At these monthly meetings the primary care internists have examined our practices in areas like appointment procedures, admission and follow up of patients in the Inpatient Service as well as at Mt. Auburn and other referral hospitals, communication with subspecialists and ways to upgrade continuing education activities here at MIT. Among the educational innovations is a combined medical/psychiatric conference, examining the interplay between somatic and psychiatric diseases. Involvement in the Health Science and Technology (HST) program provides additional stimulation for the staff in their role as tutors for these young medical students who are being introduced to clinical medicine at MIT.

Inpatient and Ambulatory Services: Michael A. Kane, Coordinator

Both services were more active this year thanks to the offering of the new Flexible MIT Health Plan option as well as to the transfer of CRC patients to the inpatient facility. Twenty-four hour physician coverage in the Inpatient Service continued into the second year providing invaluable care during the evening and night hours. In addition the MIT physician group has contributed "twilight" coverage on weekdays from 5:00 p.m. until 7:00 p.m. We now have 24 hour physician presence in the Department, seven days a week.

Ambulatory services have been enhanced by the appointment of a pulmonary and allergy disease specialist and by additional ENT, neurology and gastroenterology sessions. A program of nurse practitioner home visits for students was initiated in the spring. It is hoped that this initiative will tide students over the period between a hospitalization and return to full activity. We have also continued to participate in the training of primary care medical residents from Mt. Auburn Hospital.

In April of 1989 the Department offered an on-site Advanced Cardiac Life Support (ACLS) training course. Members of the primary care and specialist physician groups, nurse practitioners, physician assistants and several members of the Harvard University Health Service participated in this activity. The addition of physicians to the After Hours Service, their availability for emergencies involving inpatients and others, the institution of "twilight" coverage and the recent certification of many staff members in ACLS all testify to the continued dedication of care providers to better health for the MIT community.

Obstetrics and Gynecology: Charles Eades, Chief

The number of patients cared for, including the number of deliveries, increased as a direct result of additional student families and new Health Plan members. Primary infertility is now covered by many third party payers and we saw an increase in individuals seeking evaluation for this problem. Courses in childbearing, contraception, estrogen replacement therapy and other gynecological-related subjects were given through the Health Education Service.

Pediatric Service: Barbara L. O'Pray, Chief

The Pediatric Service continues to provide care for an increasing number of youngsters especially stimulated by new legislation mandating well child care up to the age of six years. We are planning early morning clinics as an expansion of

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services and clinic time. This should be helpful to working parents who would be inconvenienced by availability of clinic only during traditional working hours. The clinical staff continues to be active in teaching both at Harvard Medical School and at the Medical Department.

Psychiatric Service: Joseph Brenner, Acting Chief

The Psychiatric Service saw a 5% increase in the number of individuals seeking care. Quality care issues were of a special importance. In the surveillance of patients in outside hospitals as well as those individuals receiving therapy from outside therapists efforts were made to improve communications. Commencing in the summer of 1989 a member of the Psychiatric Service will spend part of his time providing closer surveillance of the needs of hospitalized students and Health Plan patients. A major staff change was the resignation, after 18 years, of Dr. Merton Kahne as Chief of Psychiatry. Following a sabbatical he returned to teaching at MIT and will be a research associate in the CRC. A new Chief of Psychiatry will be appointed shortly to provide continuing leadership for the Psychiatry Service. I would like to personally express our sincere appreciation, for the Administration as well as for the entire staff of the Medical Department, to Dr. Kahne for his long service and to Dr. Joseph Brenner, who has led so ably as the Acting Chief.

Social Work Service: Ronald Fleming, Chief

The clinical role of the Social Work Service in the MIT community remains substantial, through client visits, services to members of the MIT community outside of the Medical Department, participation in the Institute's Personal Assistance Program, and dealing with sensitive issues like substance abuse. The Service plays an active role in minority student activities, Tech Child Care Center, Personnel and Personnel Development Departments, MIT Lincoln Laboratory and Draper Laboratory supervisor and manager issues and various self-help groups. In addition, seminars were conducted on caring for aging parents, pre-retirement planning, and death and dying, to name a few. The Service reviews outside treatment protocols for substance abuse problems, provides assistance to physicians in the ambulatory and inpatient areas in finding appropriate community services for selected patients, and also contributes to Psychiatry Service activities.

Surgical Services: Stephen Healey, Chief

The Surgical Service has continued to provide care for MIT patients in innovative ways. This includes admission to the Inpatient Unit for initial care prior to transfer for surgery at Mt. Auburn Hospital and rapid return of patients post-operatively to the Inpatient Unit. This has been convenient for patients as well as economical for the Medical Department and provides excellent continuity of care. The Surgical Service also continues to maintain an active consultation role and performs approximately 350 minor surgical procedures yearly at MIT. Ambulatory services are provided in the general surgical and in subspecialty clinics.

Nursing Services: Janet Beyer and Maureen Dickey, Supervisors

Activities of the Nursing Service have continued to provide outstanding general nursing as well as nurse practitioner care for the MIT community. In addition to providing nursing care, nursing personnel have contributed to continuing education activities, including the provision of Independent Activities Period (IAP) programs during January. Members of the Nursing Service have served on key quality assurance committees, and have assisted the Department in developing a home health service for students. Lincoln Laboratory Coordinator Janet Beyer has continued to provide walk-in services along with Monique Cantin at the Lincoln Laboratory Campus. Other activities of the Nursing Service have included freshman health screening, nurse practitioner coverage at alumni activities, participation in planning for Medical Department disaster drills, contributions to Infection Control Committee functions and training and supervision of CRC nurses. Inpatient nursing is maintained at an outstanding humane and professional level by a dedicated staff and able leader in Ms. Maureen Dickey. The departure of Ms. Deborah Dacus, Chief of Nursing, has placed an added burden on the Nursing Staff which has responded beautifully under the leadership of Ms. Janet Beyer and Ms. Maureen Dickey.

Other Departmental Activities

Clinical Research Center (CRC): An NIH mandate led to the incorporation of the CRC into the Medical Department for matters relating to patient care. A group representing the Department and the CRC developed a set of guidelines for effecting this change, which included modification of Medical Department Bylaws, admission procedures for inpatient care, liaison functions for selected personnel from both areas, training of CRC nurses for inpatient duties and defining fiscal obligations of the incorporation. Thanks to the hard work of a number of individuals, especially Dr. H. Walter Jones, Dr. Elaine Shiang, Dr. Michael Kane and Ms. Linda Rounds, the incorporation is completed. A preliminary favorable outcome in the grant award from the NIH is expected early this summer. Dr. Richard Wurtman, Medical Director of the CRC, is now a member of the Executive Committee of the Medical Department.

Environmental Medical Service (EMS): Dr. Alan Ducatman, Chief of EMS, has met two major goals for this year have been met. Firstly, salary adjustments for professional staff has led to increased job satisfaction and to retention of valuable individuals in a very competitive market. Secondly, the computerization of the area is making headway and will lead in the near future, with Purchasing and Lab Supplies, to improved purchase, storage, tracking and disposal of chemicals. The eventual goal is to see MIT the leader in a national toxic waste reduction effort. A variety of new or expanded services accomplished this year includes: facility design consultations, increased asbestos surveillance efforts, responses to subjective workplace complaints and coordination of food sanitation efforts for the entire MIT campus.

Health Education Service (HES): Led by Janet Van Ness, the HES has continued its long-standing commitment to wellness by offering an expanded slate of behaviorally-oriented health promotion programs. Through "Staying Healthy at MIT" student health has been an especially active endeavor. A number of innovative interdepartmental programs will be implemented in the coming year including one with the Physical Education Department. Planning for an alcohol and drug prevention effort led to submission of a grant proposal to the United States Department of Education. The preliminary news is that we will be funded - allowing a coordinated program in this vital area of health education.

A variety of programs were offered this year including: "The Better Back," "Women and Fitness," "Workplace Issues and AIDS," and, during IAP, the HES coordinated 54 sessions attended by 1,379 individuals in areas relating to health issues. Overall, 4,462 individuals participated in courses and programs sponsored by the HES. Of these over 300 attended parenting and childbirth seminars, and over 1,609 were students. Through the efforts of the Student Affairs Office and the Administration a new HES office is about to open in the Stratton Student Center, staffed in the late afternoon and evening by a health educator. At the other end of a broad spectrum of activities, a second Successful Aging Seminar was presented, cosponsored by the Medical Department and the Honorary Matrons, in collaboration with the CRC and the Department of Brain and Cognitive Sciences.

Student Health Services (SHS): Dr. Mark Goldstein, Chief of the SHS reported that the Personal Physician Program was expanded during this year to include all incoming freshmen and first year graduate students. Each student was assigned a physician and provided with the doctor's phone extension in the Medical Department. In the Spring of 1988 all present freshmen and first year graduate students were surveyed. Students rated medical services on campus as satisfied to highly satisfied. Areas of dissatisfaction have led to corrective actions or better understanding of the causes for complaints. A section dealing with innovative educational methods in the area of AIDS led to the conclusion that mass media, especially newspaper articles, provided the most effective means of disseminating information. Through a series of AIDS-related questions, on information and attitudes, we found our students to be knowledgeable and sophisticated. The survey results led to a presentation at the Fourth International Conference on AIDS in Stockholm, Sweden. In the upcoming year a number of new activities are planned, including a major program on substance abuse and efforts to educate individuals about good health through sound nutrition.

Planning Initiatives

A number of major accomplishments can be reported thanks to the combined efforts of the entire department. Special appreciation must be expressed for the leadership provided by the Executive Director, Ms. Linda Rounds, the Associate Medical Director, Dr. Michael A. Kane, and the Assistant Medical Director, Dr. J. Christian Kryder.

The most significant accomplishment for MIT and for the Medical Department was the launching on January 1, 1989 of a new health insurance alternative called the Flexible MIT Health Plan. This plan allows enrollees to have their care at MIT but also to engage other physicians and hospitals for specific problems or for convenience. Approximately 1,000 individuals chose this alternative, including a group of Lincoln Laboratory employees assigned to Kwajalein in the South Pacific. We can now proudly say that the sun never sets on the MIT Health Plans! Efforts have shifted to a review and analysis of operations, to maximize the effectiveness of this new program and to be certain that patient satisfaction and cost containment are optimal. Incorporation of the CRC into the Medical Department was a second major planning function essentially completed during this calendar year, details of which are described above.

We have been studying improvement of access to Departmental services for employees of Lincoln Laboratory and MIT employees residing in the Northwest Corridor (Route 2 area between Routes 128 and 495). A survey of Lincoln Laboratory employees has been completed and potential convenient sites have been inspected. A satellite health center will require careful additional planning, including the potential for a joint project with Harvard University Health Services.

The Medical Department is close to completing the MIT Health Information System (MITHIS), which eventually will expand to provide clinical support functions in addition to patient database and billing activities. Another major planning priority for

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the coming year will be a systematic appraisal of Departmental budget issues and costs. Among the objectives receiving high priority will be the ancillary services such as the Pharmacy and the Laboratory. We have hired an Operations Analyst to gather data, analyze trends and coordinate the activities of the individuals responsible for these areas.

Direct medical care related activities that have evolved from our planning efforts include: a) revision of After Hours Service staffing by a joint physician and nurse practitioner group. After Hours Service visits have increased by approximately eight percent this year; b) the complexity of visits (serious emergencies) has increased greatly and this has moved us to re-examine the Department's overall emergency capabilities by establishing an Emergency Preparedness Task Force. This group has presented its recommendations for staff development, emergency procedure enhancement, equipment and communication needs and Quality Assurance functions. A first step in upgrading our capabilities was to offer an Advanced Cardiac Life Support Course (ACLS) in June 1989 and this has galvanized interest as we move into further planning and implementation of emergency preparedness at MIT.

Personnel Changes

Resignations and retirements during this year included:

Resignations/Retirements

Melvin Chalfen	6/30/88	Retired	Physician
Norma Loomis	7/31/88	Retired	Third Party Liaison Officer
Warnie Webster	10/31/88		Psychiatrist
Mary Pennell	12/31/88		Nurse Practitioner
Bonnie Weeks	12/31/88		Industrial Hygienist
Kathleen Marshall	1/20/89		Asst. to the Exec. Director
Mary Ramos	2/01/89	Transfer to CRC	Nurse Practitioner
F. Judith Klayman	5/19/89		Asst. Operations Manager
Deborah Dacus	5/31/89		Administrator, Dir. of Nursing Services
Laura Willett	5/31/89		Physician

Appointments

Anthony Van Niel	7/01/88	Post-doctoral Fellow, Psychiatry
Margaret Sullivan	7/11/88	Inpatient Nurse
Robert Gross	8/16/88	Optometrist
Richard Brewer	8/22/88	Manager of Administrative Services, EMS
Donald Haes	10/03/88	Asst. Radiation Protection Officer
Norma Stark	12/01/88	Inpatient Nurse
Elliott Israel	1/01/89	Physician
Mary Smith	1/20/89	Sr. Manager for Operations, MIT Health Plans

Concluding Comment

A brief report like this fails to describe the full measure of activities and tasks of a group of over 250 dedicated employees. Quality of care is maintained by the devotion of nurses, technologists, medical secretaries, physicians, non-physician and physician administrators, pharmacists, medical records and correspondence colleagues, to name some of the categories of people that make this Department successful. Our education efforts at the Medical Department and in outreach functions are no less important. The students are why this is MIT and not an Industrial-Research complex. The philosophy of leadership of this Medical Department is to never lose sight of the needs of our students, and by keeping them foremost in view we do indeed embrace this entire wonderful MIT community in offering care for those in need, and education for maintaining a healthy future.

ARNOLD N. WEINBERG, M.D.

MIT Press

Fiscal 1989 was a good year. Revenues were up about 10 percent in the books division and journals produced a surplus instead of an anticipated deficit. Foreign sales were up overall: \$2,700,000 or 28 percent of total sales. Australian sales showed a dramatic improvement as a result of our new policy to send field reps to visit customers twice a year. Textbook sales continue in a strong upward growth pattern, posting a 17 percent gain over last year, reflecting our continuing emphasis on publishing books for the student market.

While revenues from the new list in computer science and cognitive science were down from last year due to late books, new list sales overall were up about 5 percent, with revenues of \$3,400,000. The shortfall in computer science and cognitive science was made up for by the new architecture/design and photography lists. Backlist sales, that is, all the books published prior to Fiscal 1989, continued a strong growth trend, with a 13 percent increase over last year. Continued improvement in backlist sales reflects the results of our continuing emphasis on the text market.

We published 156 titles: 123 original publications, and 33 paperbacks reprinted from our own hardcover backlist, 12 fewer than last year. Unit sales were up 8 percent to 600,900 copies.

Some highlights: Another solid year of performance of The MIT Press Bookstore, with sales up 18 percent to \$475,000. Made in America: Regaining the Productive Edge, based on a study completed by the MIT Commission on Industrial Productivity was published in May with great fanfare (major press conferences in New York and Washington D.C., feature articles in Fortune and Scientific American, and a \$45,000 ad budget). At the end of June there were 25,000 copies in print and a third printing on order. Japanese and French translation rights have been sold for record advances.

After a head-to-head competition with several commercial publishers, we concluded negotiations with the American Association of Artificial Intelligence to establish a joint publishing program under the colophon of the AAI Press. We also made the first steps in the direction of expanding our Natural History program, and in enlarging our program in ecology/environment.

Our European office in London has been restructured. Chicago, who established the office twenty years ago, left the partnership on December 31, 1988. The MIT Press is now sharing staff and space with Harvard University Press. We completed negotiations with John Wiley to transfer our warehousing and fulfillment operations from IBD (Simon and Schuster/Prentice-Hall) where we had been since 1969. Wiley promises superior service at a better price.

Finally, our performance this year has allowed us to write off \$250,000 of our accumulated deficit (held on the balance sheet since the early eighties). This will reduce the deficit carried in MIT's Pool D, with the net effect of producing about \$20,000 interest revenue per year for MIT. Our plan is to reduce the remaining accumulated deficit (\$200,000) at the end of the current Fiscal 1990. Final note: Frank Urbanowski has been elected President of the American Association of University Presses for Fiscal 1991, beginning mid-June, 1990.

Bestsellers from the Fiscal 1989 list included:

Albertini	<u>Carlo Scarpa</u>
Blanchard & Fischer	<u>Lectures on Macroeconomics</u>
Dertouzos et al.	<u>Made in America</u>
Feher	<u>ZONE 3/4/5: Fragments for a History of the Human Body</u>
Gottschall	<u>Typographic Communications Today</u>
Graubard	<u>Artificial Intelligence Debate</u>
Moore	<u>Poetics of Gardens</u>
Remington & Hodik	<u>Nine Pioneers in American Graphic Design</u>
Tirole	<u>The Theory of Industrial Organization</u>
Weiermair	<u>The Hidden Image</u>

Titles which produced the best margins in Fiscal 1989 included:

Dertouzos et al	('89) <u>Made in America</u>
McClelland et al	('88) <u>Parallel Distributed Processing: Programs and Exercises, IBM ve</u>
Anderson	('88) <u>Neurocomputing Foundations</u>
Rumelhard et al	('88) <u>Parallel Distributed Processing, two volumes</u>
Tirole	('89) <u>The Theory of Industrial Organization</u>
Weiermaier	('89) <u>Hidden Image</u>
Sterling and Shapiro	('87) <u>The Art of Prolog</u>
Abelson and deSessa	('85) <u>Structure and Interpretation of Computer Programs</u>
Gottschall	('89) <u>Typographic Communications Today</u>
Akmajian	('84) <u>Introduction to Linguistics, second edition</u>

MIT authors:

Barrett	<u>The Society of Text</u>
Blanchard & Fischer	<u>Lectures on Macroeconomics</u>
Dertouzos et al.	<u>Made in America</u>
Dornbusch	<u>Exchange Rates and Inflation</u>
Fischer	<u>NBER Macroeconomics Annual 1988</u>
Helpman & Krugman	<u>Trade Policy and Market Structure</u>
Kindleberger	<u>The International Economic Order</u>
Krugman	<u>Exchange-Rate Instability</u>
McAllester	<u>Ontic</u>
Pinker & Mehler	<u>Connections and Symbols</u>
Shrock	<u>Cecil and Ida Green</u>
Tirole	<u>The Theory of Industrial Organization</u>

Among the noteworthy books by non-MIT authors:

Boden	<u>Artificial Intelligence in Psychology</u>
Canguilhem	<u>Ideology and Rationality in the History of the Life Sciences</u>
Cummins	<u>Meaning and Mental Representation</u>
Habermas	<u>On the Logic of the Social Sciences</u>
Habermas	<u>Structural Transformation of the Public Sphere</u>
Handel	<u>Listening</u>
Howard & Franklin	<u>Missing the Meaning</u>
Kanerva	<u>Sparse Distributed Memory</u>
Koch & Segev	<u>Methods in Neuronal Modeling</u>
Kotlikoff	<u>What Determines Savings?</u>
Levelt	<u>Speaking</u>
Lindbeck & Snower	<u>The Insider-Outsider Theory of Employment</u>
Oakes	<u>Weber and Rickert</u>
Pierrehumbert & Beckman	<u>Japanese Tone Structure</u>
Spulber	<u>Regulation and Markets</u>
Vickers & Yarrow	<u>Privatization</u>

Additional titles for trade and general audiences included:

Becher	<u>Watertowers</u>
Ceruzzi	<u>Beyond the Limits</u>
Colquhoun	<u>Modernity and the Classical Tradition</u>
De Long	<u>Bruce Goff</u>
Donahue	<u>The Battle to Control Television News</u>
Gansler	<u>Affording Defense</u>
Goldstein	<u>A Forest of Signs</u>
Krinsky	<u>Gordon Bunshaft</u>
Lavrentiev	<u>Varvara Stepanova</u>
Manzini	<u>The Material of Invention</u>
Rabinow	<u>French Modern</u>
Smith	<u>The Photography of Invention</u>
van Leeuwen	<u>The Skyward Trend of Thought</u>
Voous	<u>Owls of the Northern Hemisphere</u>

Books published primarily as core texts for advanced courses:

Baker	<u>English Syntax</u>
Blanchard & Fischer	<u>Lectures on Macroeconomics</u>
Laffont	<u>The Economics of Uncertainty and Information</u>
Tirole	<u>The Theory of Industrial Organization</u>

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Editors in the Acquisition department include: Frank Satlow (Computer Science and Artificial Intelligence); Terry Ehling (Computer Science and Artificial Intelligence); Robert Prior (Computer Science and Artificial Intelligence); Laurence Cohen (Science, Philosophy and Linguistics); Fiona Stevens (Neuroscience); Roger Conover (Architecture & Design Arts); Terry Vaughn (Economics and Management); Henry and Elizabeth Stanton (Cognitive Science); and Joanna Poole (Assistant Acquisitions Editor).

BOOK PRODUCTION

Under the direction of Helene Osborne, managing editor, and Dick Woelflein, production manager, the editorial and production departments continued to add quality to our publications. The design department, under Diane Jaroch, upheld the Press tradition of award-winning jacket and book design, garnering honors from the New England Book Show, the Association of American University Presses, the Art Director's Show of Boston, Print Magazine, The American Institute of Graphic Arts, and International Design Magazine.

COMPARATIVE OPERATING RESULTS (in thousands)

	<u>Fiscal Year</u> <u>1989</u>	<u>Fiscal Year</u> <u>1988</u> <u>Actual</u>	<u>Fiscal Year</u> <u>1986</u> <u>Actual</u>
Total Net Book Sales	\$ 9,706	\$ 8,830	\$ 7,941
Cost of Sales	<u>4,242</u>	<u>3,721</u>	<u>3,408</u>
Gross Margin on Sales	5,464	5,109	4,533
Other Pub. Income	126	167	135
Bookstore Net	<u>95</u>	<u>90</u>	<u>40</u>
Total Income	5,685	5,366	4,708
Operating Expense	<u>5,814</u>	<u>5,292</u>	<u>4,841</u>
Net Books Division	(129)	74	(133)
Journals Net	<u>42</u>	<u>4</u>	<u>(113)</u>
	(87)	78	(246)

Faculty serving on The MIT Press editorial board in 1988-1989 were Professors Harold Abelson, John de Monchaux, Richard Held, John P. Longwell, Peter Diamond, Albert Meyer, Daniel Osherson, Merritt Roe Smith, Robert Solow 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 once during the year. Members of the board are Robert M. Solow, Professor in the Department of Economics, Christopher T. Walsh, Head, Department of Chemistry; Ann F. Friedlaender, Dean of the School of Humanities and Social Sciences; 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; Arthur L. Singer, Vice President of the Alfred P. Sloan Foundation, and Robert L. Solow, Professor in the Department of Economics and Chairman of The MIT Press Editorial Board. Robert M. Solow, Chairman of The MIT Press Editorial Board, 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 complexion of our list continues to reflect our intention to devote most of our resources to building depth in our programs in architecture and design arts, computer science and artificial intelligence, cognitive science and neuroscience, linguistics, economics and philosophy, with the balance of our efforts devoted to publication of important works in science, technology and society, and in science and engineering.

BOOK SALES

<u>Customer Type</u>	<u>Fiscal Year 1987</u>	<u>Fiscal Year 1988</u> (in thousands)	<u>Fiscal Year 1989</u>
College Bookstore	\$ 1,531	\$ 1,501	\$ 1,781
Retail Bookstore	1,685	1,774	2,225
Wholesaler/Jobber	1,475	1,750	1,844
College/University Library	175	164	130
Direct Mail	746	584	512
To Individuals	<u>592</u>	<u>755</u>	<u>880</u>
TOTALS	6,204	6,527	7,373

Under the direction of Tom McCorkle, this was another good sales year for the Press. Total sales increased from \$8,830,300 to \$9,706,200, or by about 10 percent. Also encouraging was the growth in units sold -- from 562,340 to 608,788, or about eight percent.

INTERNATIONAL SALES

A sharp decrease this fiscal year in the number of new titles with international appeal limited sales growth in most countries outside the U.S. Sales in Australia and New Zealand moved against this trend as continued restructuring of The MIT Press' sales and marketing program there produced significant positive results for the third year in a row. Canada, which more closely mirrors the U.S. market, produced a revenue increase very close to that achieved in the U.S. Book purchases in developing countries were in most cases sharply down because of political turmoil and the absence of special sales opportunities.

International Book Sales FY 1987 - 1989

	<u>Fiscal Year 1989</u>	<u>Fiscal Year 1988</u>	<u>Fiscal Year 1987</u>
Australasia	\$ 122,300	\$ 83,100	\$ 63,800
Canada	409,500	356,100	308,200
Japan	450,000	428,900	520,400
Rest of Asia/Other	352,500	438,000	256,840
UK/Europe	<u>1,365,700</u>	<u>1,361,000</u>	<u>902,200</u>
TOTAL EXPORT	2,700,000	2,667,100	2,051,440
percent of total sales	27.8	30.2	25.8

SUBSIDIARY RIGHTS

The core of the subsidiary rights program continues to be translation rights sales, which are less subject to wide annual fluctuations than are sales to bookclubs. The translation market for our titles continues to grow, especially in cognitive and computer science.

This year's income derived from permissions and other English-language use of our material increased significantly, almost doubling last year's income in this category. This is due in large part to the addition of a permanent part-time permissions clerk to our staff, and to the renewal of the sale of English language reprint rights to Taiwan. For a number of years, U.S. copyright was not protected under Taiwanese law. This situation has changed and this market will continue to grow.

Sales to book clubs in FY89 went up by 33 percent. However, changes in ownership, personnel, and editorial policy in the book clubs indicate that they will be more conservative in their purchases in the future. Finally, audiovisual sales depend on the number of new videotapes issued by the Press. While FY88 yielded almost \$9000 in this category, the income for FY89 was \$1400. This could vary widely from year to year.

Total subsidiary rights income increased by 17 percent in FY1989.

Subsidiary Rights Income FY 1987 - FY 1989

	<u>Fiscal Year 1989</u>	<u>Fiscal Year 1988</u>	<u>Fiscal Year 1987</u>
Translation Rights	\$ 104,998	\$ 98,509	\$ 87,449
Book Club Rights	61,281	46,046	71,924
Reprint Rights	29,499	15,093	14,773
AudioVisual (new category)	<u>1,400</u>	<u>8,726</u>	<u>----</u>
	197,179	168,374	174,146

PROMOTION AND DIRECT MARKETING

Text sales topped \$2 million for an increase of 16 percent in FY'89. Unit sales (177,689) increased by 16 percent. The leading titles were Tirole/The Theory of Industrial Organization, Rumelhart & McClelland/Parallel Distributed Processing, and Explorations in Parallel Distributed Processing.

MIT Press books were mentioned or featured in over 2,000 reviews. Of these 216 were major single-book reviews. There were over 300 multiple wire service reviews and articles. The publication of Made in America was without a doubt Publicity's biggest project. To date the book has been mentioned in 172 wire service articles, 27 independent articles and reviews and 5 editorials.

Advertisements for books appeared in 294 trade and scholarly journals and magazines, compared with 261 last year. Of particular note was the campaign for Made in America which included advertisements in The New York Times National Business Section, the Times Book Review, Harvard Business Review, Technology Review, Sloan Management Review, Columbia Journal of World Business, National Productivity Review, The New Republic, and The Economist.

For the first time, the net contribution to sales from the Exhibits Program exceeded \$100,000, a 52.4 percent increase in sales. Sales were particularly strong at the Allied Social Sciences (\$18,680), the American Association for Artificial Intelligence (\$10,637) and the Society for Neuroscience (\$8,386). Best selling books were Tirole/The Theory of Industrial Organization, Blanchard/Lectures on Macroeconomics, Rumelhart & McClelland/Parallel Distributed Processing, and Explorations in Parallel Distributed Processing, and Anderson/Neurocomputing.

Direct mail sales continued to decline from a high of \$746,400 in 1987 to \$513,786 in 1989. This decrease can be attributed in part to the lack of single high-priced mail-order titles such as the Encyclopedic Dictionary of Mathematics, or Georges Bank, and the large number of new titles in computer science and cognitive science that were announced but not released in FY89. These subject area catalogs showed the poorest returns in several seasons. The economics catalogs however showed sales increases of 27 percent (\$46,595) for the Fall mailing and 77 percent (\$37,568) for the Spring mailing.

JOURNALS

The past year has been productive and full of change. Four new publications entered the program, two of them start-ups in new disciplines. One journal, Places, was terminated, but was picked up by another publisher. The journals division had gross sales of \$2.4 million, a twenty percent increase over last year. The program concluded the year with a \$42,000 net surplus, instead of a deficit which had been budgeted.

The additions to list were Computational Linguistics, Design Issues, Journal of Cognitive Neuroscience and Neural Computation. The start-up journals, Journal of Cognitive Neural Computation and Neural Computation, have both exceeded their subscription targets for the first year.

There are now twenty-one journals in the program. The others include: Assemblage, Computer Music Journal, Design Quarterly, The Drama Review, Journal of Interdisciplinary History, International Organization, International Security, Linguistic Inquiry, Materials and Processing Report, Mimar, NBER Macroeconomics Annual, October, The Quarterly Journal of Economics, The International Journal of Supercomputer Applications, Tax Policy and the Economy, and The Washington Quarterly.

FRANK URBANOWSKI

Personnel Office

A major portion of time was allocated to the successful implementation of the new Pension Plan. Deborah A. Kelley, Manager of Benefits, led an extraordinary communication effort in the community for which she deserves acclaim.

Recruitment of support staff continues to be a challenge, however the combination of more creative advertising, more flexible interviewing schedules, and broader outreach has been quite successful.

High capacity personal computers have become important office tools as we strive to meet the constantly increasing demand for more sophisticated reports and analyses of data. With the assistance of an information systems consulting firm we began a functional analysis to determine our future business information systems strategy. The first phase concentrated on examining the existing environment in which the Personnel Office operates. Extensive interviews were conducted to determine how the current system functions and how adequately we are addressing the needs and concerns of the community. We are now in phase two of the process exploring the availability and compatibility of hardware and software options to lead us to a more rational database management system.

The strategic review of benefits continued with much of the time of the Committee being devoted to discussions on development of the Pension Plan.

Training and development programs were offered in a very limited way. With the departure of the manager of the Personnel Development section, we have taken the opportunity to rethink our goals in offering training. Programs were provided at the specific request of departments, however very few programs open to all community were offered.

Staffing changes that occurred included the promotions of Tracey A. Springer and Kathleen Avison from Administrative Assistants in the Benefits Office to Benefits Counsellors. Ramona B. Alston joined the staff as Personnel Officer for the Research areas and Edward L. Courtney as Benefits Administrator Supervisor. Sherry H. Capano and Barbara McDonald left positions in the Benefits Office, Sherry to England with her husband who received his doctorate from MIT, and Barbara to a position in Resource Development. Susan Warshauer left to take a position in industry after ten years of fine work in the design and presentation of training programs.

JOAN F. RICE

COMPENSATION OFFICE

The Compensation Office worked to provide fair and equitable salary administration across the Institute through the annual review process, in the review and analysis of individual salary increase, and promotion recommendations submitted by department supervisors throughout the year. Approximately 8,300 individuals, both on campus and at Lincoln Laboratory, received consideration for salary adjustment this year through these individual and annual merit reviews.

Allocations for merit reviews are determined through the review of conditions as they exist in the marketplace appropriate to each payroll group. We analyze the Institute's position in the marketplace through participation in approximately 35 salary surveys during the year, including the MIT Faculty Salary Survey, the MIT Research and Development Survey, the MIT

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Administrative and Professional Salary Survey, and two major Boston-area Support Staff salary surveys.

Twenty-six universities participated in MIT's 1988-89 nationwide Faculty Salary Survey, a survey run for over twenty years by the Wage and Salary Office. We provided extensive analysis of the Survey data to the School Deans and to other Senior Officers prior to the Faculty salary review in February.

Twenty-two universities and fourteen area employers participated in MIT's Fall 1988 Administrative and Professional Salary Survey. This survey, now in its fourteenth year, surveys 40 benchmark positions on the administrative staff for comparison of average salaries, salary ranges, and similarity of organizational structure.

The addition of new, high capacity personal computers has enabled the Compensation Office to download a comprehensive employee database for each of the Institute's payroll categories. This new capability greatly enhances our ability to conduct salary surveys, equity studies, merit review preparation, and statistical research. During the months ahead we look forward to developing our skills in this area

A total of 139 requests for reclassification on the Administrative Staff were received during the year: 56 requests to assess newly created positions; 9 promotional requests for individuals moving from Support Staff; 46 requests to reevaluate existing positions and their salary ranges; and 28 requests for title changes. In reviewing these requests, we have continued to rely on organizational charts which display structures of departments as well as entire organizational areas. These charts have become a valuable tool in illustrating for Senior Officers the departments which report to them, and in determining comparable structures in new departments.

KERRY B. WILSON

BENEFITS OFFICE

The Benefits Office was restructured on January 1 into three units: Administration, Systems and Information, and Development and Communications. The Administration unit consists of eight individuals who are directly responsible for responding to employees' inquiries on all benefit matters. Work is divided by an alphabetical split, and members of the community have been requested to direct their inquiries according to this split. A generalist approach was implemented in this group to support backup requirements, to create depth in the department and to provide career growth. Our Systems and Information unit handles the development of systems to administer our numerous programs, maintains the integrity of benefits information on our database, provides reporting and disclosure information to the Internal Revenue Service, and administers the Tuition Assistance and Children's Scholarship programs. The Development and Communications unit is directly responsible for maintaining up-to-date benefit materials, developing new materials, keeping us abreast of legislated changes in our benefit programs and maintaining competitive survey data.

The Benefits Office went through an aggressive and intensive retraining program to prepare for the restructure, including classroom training provided by outside plan vendors, consultants, other benefits specialists, and members of other internal departments.

We experienced a 40 percent turnover this year, primarily as a result of this restructure and changing roles within the office. We have filled all of the open positions with the exception of one Administration Supervisor and the secretary.

We responded to over 40,000 telephone calls and to 5,000 employees who visited the office during the year. Prior to the restructure we were unable to respond to 30-35 percent of the calls that came into the office. The restructure has improved the loss ratio from 50 percent to 15-18 percent. In March, we developed and implemented an interactive telephone system called BenTalk. The system was designed to provide general information on all of the Institute's benefit programs. While we have not experienced a decrease in the number of direct calls to the office, BenTalk does currently service another 300-500 calls per week.

The Systems and Information unit completed Phase I of the design and implementation of a mainframe application to administer the Children's Scholarship program. This system tracks eligibility, determines the amount of benefit available, generates periodic verification notices to parents and schools, produces a check run, and provides various reports and statistical data.

We purchased a software application to administer both the notification and premium billing requirements for continuation of health and dental plan coverage under the Consolidated Omnibus Budget Reconciliation Act of 1985. We had experienced significant record keeping problems over the last two years due to billing problems, and lack of coordination between our office and the Benefits Accounting Office. The time consuming process of monthly billing has been converted to a coupon approach, and the up-to-date information of an individual's payment record is now accessible to our office, which significantly increases our responsiveness to inquiries.

The Institute announced the establishment of a unified retirement plan for the faculty, academic, research, administrative, and support staffs. Participation by the union groups is subject to collective bargaining. Over this past year the final development of the program emerged and the Benefits Office planned and executed implementation and communication programs. A total of 26 community and special focus group information meetings were conducted over a five week period. Information materials were developed, including a summary plan description, comparison chart, Tech Talk articles, and a brochure on savings opportunities in the new plan. A personalized statement of retirement plan benefits, along with an information package to enroll or change elections for the new plan was delivered to every benefits eligible employee. A telephone enrollment system was introduced and it met with limited success. We worked with the Benefits Accounting Office and with an outside consulting firm on the changes to the Pension Accounting System to develop a new pension calculation system to be used for pension estimates and projection requests.

DEBORAH KELLEY

FACULTY AND STAFF INFORMATION SERVICES

The Faculty and Staff Information Services Office processed more than 14,300 appointments and changes. This was an increase over last year's activity. The office also produced approximately 11,700 letters in support of faculty and academic appointments, and non-academic payroll status changes.

The Faculty and Staff telephone directory was published by the same vendor responsible for producing the Student Directory. The Office of Public Relations extended its services to act as liaison between this office and the new vendor. The joint effort by both offices worked extremely well.

The Faculty and Staff Information Services Office continued its role in the processing of the various salary reviews. An electronic file was sent to the Payroll Office of the Comptroller's

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Accounting Office for automatic update for the support and service staff reviews. This was a more efficient process and saved the Payroll Office several days of manual keying.

There continues to be a substantial increase in the demand for reports. Various administrative departments requested personnel data to be downloaded to systems set up on their local personal computers. Other computer-related accomplishments were the completion of Easytrieve conversions to NATURAL and the addition of several new fields to the personnel database.

CLAIRE L. PAULDING

LABOR RELATIONS

The Institute opened negotiations with the Research Development and Technical Employees' Union (representing employees in all departments, laboratories and centers of the Campus, Millstone Hill and Lincoln Laboratory) and two units of the Service Employees' International Union, Local #254 (representing employees on Campus, at the Lincoln Laboratory and Haystack Hill) early in March of this year. The Campus Police Association chose not to start bargaining until May. The major issues before the parties are wages, cost of health care, the transitional issues for the new MIT Retirement Plan, and local unit issues. The Independent Union for Plant Protection Employees' Union Local #14 (representing Security Officers at the Lincoln Laboratory) has a signed two-year Agreement with the Institute. This Unit was offered and accepted the new pension plan in May. All members of this unit are in the new plan effective July 1, 1989. The total cost of wages and benefits are being addressed at the Table by the Institute Committees. An equitable conclusion to these negotiations is being mutually pursued; however, the transitional issues leading to the new pension plan are going to be a difficult barrier to a satisfactory conclusion to the bargaining.

The Campus Police Association, under the leadership of a new law firm, has filed a series of charges and amended charges before the National Labor Relations Board. The major issue placed before the Board was the right of the Association's lawyer to represent members in meetings with the department head. The Agreement and past practice has restricted the legal representatives to the Negotiation Table and the arbitration process. The Washington Board, when asked for an opinion on this matter responded that it was a non-issue. After a new amendment was added to the charge, the Boston Office decided to schedule a hearing on this issue in August, 1989. This unit has continued to file numerous grievances and arbitration demands. Arbitrations are scheduled for later this summer and early fall. The promotional grievance/arbitration issue with this unit that dragged on for several years was recently decided in favor of the Institute.

The workload of this Office has shifted away from the burdensome presentation of arbitration cases to a successful dialogue of issues with all other bargaining units (excluding the Campus Police Unit). Michael J. Parr, Assistant Manager of Labor Relations has managed the 2A Classification process by dialogue with his counterpart in the Research Development and Technical Employees' Union with the best results we have had in years on classification matters. Grievances continue at a modest rate. Arbitrations have been limited to seven in the past year.

JAMES J. FANDEL

PERSONNEL SERVICES AND EMPLOYMENT

The responsibilities of Personnel Services include developing, interpreting, and implementing personnel policies and procedures. Personnel Services also provides counsel and advice to members of the Institute in relation to personnel matters, and interviews and refers applicants for open positions.

During the past year the primary focus of Personnel Services has been to address the challenges presented by the rapidly changing cultural and economic demands of an extremely knowledgeable workforce. Employees increasingly desire greater responsibility and career opportunities related to their work and this has required devising more creative ways to deal with work environment concerns. Closely related to this factor has been the need to work with supervisors and administrators to provide new concepts of leadership and management to respond to changing workforce values.

A significant accomplishment in another area of responsibility has been the review and update of the Personnel Policy Manual. This was completed by an Institute-wide committee coordinated by Cynthia Froeber. The design of the new manual allows for future changes in personnel policy and other related information to be inserted as needed.

A handbook for new employees entitled You and MIT is also being revised and will be available by late 1989. This handbook, widely used in the past, discusses policy, benefits and services available at MIT. It is an excellent source of information for new as well as current employees. In addition, the Institute's Affirmative Action Plan is also undergoing revision.

Another major accomplishment has been further automation of personnel information so that new sources of data are now available to the MIT community. New programs have been developed to assist administrators with decisions related to personnel matters.

Employment Activity

Recruitment of qualified applicants for open positions continues to be a significant challenge to the Personnel Office. A new recruitment advertising agency was engaged to work with the Personnel Office to design more creative and diverse efforts to meet the recruitment challenge. Several new activities were conducted during the past year which had a significant impact on reducing the number of openings experienced. In addition, the number of interviewing hours was increased as well as a more flexible interviewing schedule implemented so that more applicants could be accommodated on a regular basis. A program of broad outreach was extended which resulted in noticeable success. The recruitment program was highlighted by an Open House which produced a large number of applicants and filled more positions than any other recruitment event in past years. Working with cooperation of departments, the above efforts will continue and new recruitment activities will be implemented.

This past year 1,071 vacant positions were posted. Personnel Office staff interviewed 1,077 applicants, a 29 percent increase over 1988. The total applicant pool was 10,868 which is 44 percent more than the year before. A total of 902 individuals were hired as new employees, and 203 employees transferred into new positions within the Institute.

SUSAN P. GASKELL

CHILD CARE

The MIT Child Care Office was established in 1972 to provide members of the MIT community with a central location in which to find education and support services offering help with child care and parenting and to offer coordination to MIT's involvement in child care issues. As the nature of work/family needs has changed and broadened the Child Care Office has attempted to monitor local and national issues and to guide and coordinate MIT response. Significant efforts were made to increase the range of services and resources available within the Office, to increase collaboration with other areas of the Institute, and to provide information and expertise to support Institute policy discussions.

During fiscal 1989, the Child Care Office has acted as staff to the MIT Committee on Family and Work, provided orientation to the Committee by assisting in planning and agenda-setting, introduced appropriate consultants, developed a survey on work-family issues distributed Institute-wide, and served generally to locate resources and information for the Committee on demographic shifts, government policy, and the range of Institutional response to these changes.

Services within the Office have broadened. The Child Care Office developed a comprehensive year-long series of parent education workshops and lectures led by Office staff, other MIT experts and outside guests; assumed the role of co-sponsor to the Working Parents' Support Group; expanded fourfold the Office's lending library of books and articles on child care, work and family, and childrearing; and increased information on an expanded range of community resources to which it can refer parents for assistance. The Child Care Office has increased its visibility within MIT through co-sponsorship of several well-attended Institute lectures, and outside MIT through increased participation in a number of regional and national organizations, including the Employer-Supported Child Care Network, the National Campus Child Care Coalition, and American Association for the Advancement of Science.

Support and technical assistance to on-campus child care programs and providers included the development of a 200-page handbook for family day care providers; meetings with the Child Care Committee at Lincoln Laboratory exploring on-site child care options; participation on Technology Children's Center board of directors and chairmanship of the board's Planning Committee which explored methods of increasing the cost-effective use of space and program affordability within the MIT community; and exploration of options on campus for assisting parents with day care for mildly ill children and emergency/back-up child care.

Use of Child Care Office services continued to increase in FY 1989 over 400 families contacted the Office for assistance locating child care, quality schools, summer camp programs or special children's services, representing a 50 percent increase over the previous year. Additional MIT families participated in workshops, support groups, the Children's Swim program, and special events.

At Technology Children's Center, Olga Slocum became the new director following Caren Nemtzow's departure in May. TCC extended certain program schedules so that now all programs operate year-round. Waiting lists continue to average 50 children per program, half-day and full-time. A continued shortage of trained early childhood professionals nationwide has been particularly acute in the Boston area and stressed administrative efforts to provide continuity; the staff turnover rate has remained around 50 percent per year. Budget-setting priorities contend with both the need to increase staff salaries and to address program affordability; in FY 1989 salary increases averaged 7.75 percent while the tuition increase of 7.5 percent brought full-time tuition to \$630/month.

KATHY SIMONS

Public Relations Services

The year just past saw a significant increase in MIT's visibility in the media, primarily through the public relations initiatives of the News Office. Widespread attention was given to: the need for greater public understanding of science and technology, industry-university relations, the arts at MIT, and athletics at MIT, among other issues.

Major advances in electronic publishing and communication were made in all areas including the use of computers in design, in typesetting and formatting the catalogue, and in compiling records and generating reports.

I would like to take this occasion to salute Jacqueline S. Casey and Ralph M. H. Coburn, both of whom retired this year after over three decades of service in Design Services at MIT. Jackie, as Director, and Ralph, as senior designer, set extraordinary design standards. The quality of their work has brought national and international accolades to MIT's publications, and we will do our best to continue the tradition of vision and excellence that they have set.

KATHRYN W. LOMBARDI

COMMUNICATIONS OFFICE

This past year, desktop publishing has played an increasingly major role in the Office's mandate of providing a cyclical series of publications for the Institute.

During the fall, production work on the large and small editions of the *Report of the Treasurer* and similar editions of the *Report of the President* took its normal course. While the use of computers, publishing software, and laser printers did not occur with these publications this year, the anticipated introduction of such methods within the next twelve months will require changes in the way these four pieces are handled. *Tech Talk* supplement issues prepared by the Office once again included Dr. Gray's annual report to the MIT Community (November 9, 1988) and the Committees of the Institute listing (November 30, 1988).

Production of the Student and Staff Telephone *Directories* (as separate documents for the various segments of the Institute community) were coordinated through this office for the first time; the actual presswork was handled once again by a North Carolina-based directory publishing company. The inclusion of advertising in both *Directories*, and the monies collected from area and on-campus vendors buying ad space, helped save the Institute more than \$15,000 in pre-press production costs. All material not typeset by the directory company was provided camera-ready from the Office's computer system.

The winter proved to be very busy, as the Office produced camera-ready copy in-house not only for the 1989 edition of the *Summer Session Catalogue*, but also for the 1988-89 *Members of the Faculty* picture book. The picture book, the first one produced in almost 20 years, contained photographs and information on the Institute's 900-plus faculty in the ranks of full, associate, and assistant professor and proved to be a most interesting and challenging project. Special thanks go to Corinna Vanderspek who served as

Production Assistant and was responsible for the day-to-day scheduling of photo sessions and collection of information. The finished book made its appearance on campus in early May.

Efforts this spring to establish an electronic link with the Registrar's Office, in order to telecommunicate between computer databases in both offices the subject description information managed by the Registrar's Catalogue Division and published in the *Courses and Degree Programs* catalogue, proved unsuccessful. Nevertheless, contents of the entire catalogue for the 1989-90 edition are now "on-line," and can be accessed and updated throughout the year. Work will continue on telecommunication technology specific to the Office not only for the catalogue but for other pieces as well. To that end, the Office is expanding its capacity to serve as in-house "typesetter" by upgrading the existing VAXstation hardware and purchasing an additional terminal.

Personnel Changes

Eve Sullivan was hired in the fall to replace Margery Wilson as a part-time Editorial Assistant for the Office. She left, however, in the spring to devote increased hours at the *Annals of Physics* (within the Department of Physics), where she also works part-time. The position and its responsibilities are currently being reviewed in the hopes of ultimately provided the Office with more streamlined part-time staffing.

MARK WILSON

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 Office, Resource Development, the School of Engineering, the Sloan School of Management, the Medical Department and the Summer Session Programs. Included among special events this year were the Dedication of the Stratton Building and Event 128: A Salute to Founders.

Overall the office undertook 298 graphic design and publishing projects in 1988-89.

In the computer area, the Office of Design Services has made great progress. Over the past year more than 50 jobs have been produced with the department's desktop publishing system, including the 104-page *MIT Founder's Day Book*, which profiles MIT alumni who have founded companies in the Boston area. Projects that did not require complex formatting, such as letterheads, invitations and simple brochures were done entirely on computers. More complicated publications, such as books, which included halftones and a variety of design elements, were produced by a combination of electronic publishing and manual methods.

Electronic publishing has provided greater flexibility and accuracy during the early stages of the design process. Our staff can generate proofs on the laser printer and make decisions quickly without the added time and cost of trial-run typesetting. This, in

turn, has enabled us to pass on significant cost savings to our clients in the area of typesetting. We now have many customers who will supply manuscript copy on floppy diskettes, eliminating the need for the typesetter to keyboard the text.

With the addition of a Mac II and color printer, we hope to expand our computer base to reach a wider clientele.

Among the members of our Office who recently completed their careers at the Institute during this academic year were Ralph Coburn, 31 years, and Jacqueline S. Casey, 34 years. On behalf of the members of our office and others at MIT who worked with them, we thank them for their contributions, dedication and talent, and wish them well in a new phase of their lives.

CELIA METCALF

INFORMATION CENTER

The Information Center is charged with providing service and information in print, in person, and over the telephone to the MIT community and to visitors; assisting the international faculty and staff; and coordinating Institute dedications, meetings, and conferences.

Public Relations and Information

Historically the Center acts as a clearinghouse for mail addressed to MIT; maintains the official Institute mailing list; answers and directs to other offices telephone and office inquiries from the public and MIT community; distributes over 45,000 pamphlets, brochures, guides, and catalogues; maintains records and publishes a *Tech Talk* supplement describing and listing memberships of faculty and presidential committees. General tours of the Institute are conducted through the Center by MIT student guides who are members of an honor society established for them. The tour guide captain, Michael Casagrande, '89, scheduled 25 student guides to conduct tours for 7,285 visitors. Alex V. Chachkes, '91, and Jeehoon Yap, '90, served the Institute as full-time guides during the summer months. During the past few months, the director has been working with an ad hoc planning group to develop and outline a program for a computer-based campus information network. The goal of this working group is to establish a long-term program on an electronic access system, providing information on MIT events, activities, and programs.

Arrangements were made for 23 delegates and 5 greetings to be sent to other universities' inaugural ceremonies.

The Center acted as a clearinghouse for 1,195 non-sponsored international visitors who were given tours or had meetings set up with faculty and academic staff. There were over 350 international visitors sponsored by the Department of State, the International Communications Agency, the Institute of International Education in Washington and

New York, embassies, and other private agencies whose meetings and visits to departments and research groups were arranged by the Information Center.

International Visitors Office

Visa applications continued to increase with many involving special expertise and individual problem solving. Problems regarding extension of stay by Chinese scholars increased steadily all year and were brought to crisis by the events in Beijing in June. A substantial amount of time was spent all year trying to work out solutions but the options became more limited, and at this writing, there is much confusion and uncertainty about what lies ahead. Nevertheless, it is clear that there will continue to be intense pressure on the International Visitors and Students Offices to assist the approximately 300 Chinese scholars and students on campus and their families. Computerization has been a welcome addition to the office but has brought a new set of issues and problems which we have not finished dealing with. Jennifer Stephens ably assisted the head of the International Visitors Office on a part-time basis during the academic year. M. Travis Stier, '91, worked inputting data on international faculty and research staff into the computer.

Conference Services

The Conference Services Office managed the logistical arrangements of 15 on-campus conferences which brought 3,000 visitors to the campus. The Massachusetts Special Olympics returned for the Summer Games in June; more than 2,000 spectators viewed the competition which was comprised of 1,800 athletes. This office also handled the arrangements for 100 on-campus recruitment presentations in conjunction with the Office of Career Services and Preprofessional Advising.

Special Events

The highlight of the year was Commencement; the day could not have been brighter, sunnier, or happier. One thousand eight hundred sixty-four graduates received 2,050 degrees. Graduates, families, and friends cheered as 1,000 balloons ascended above the great dome in Killian Court as the last diploma was presented. The Class of 1939 marched 30 members strong, marshaled by classmates Peter M. Bernays, William S. Brewster, William K. Curren, and Charles Wang. The President's Reception, held in the areas surrounding McDermott Court, was a colorful and happy celebration as Professor S. Jay Keyser, Associate Provost, led the Intermission Trio Plus to feet stomping renditions among smiling faces and picture-taking guests.

Personnel

Virginia Lyons, who has served the Institute's international faculty and research staff conscientiously and with dedication for 16 years, left MIT to devote herself to full-time graduate study. She has been an invaluable colleague and good friend and will be missed not only by this office but by the Institute in general. She leaves with our warmest good wishes for a happy and successful future. Frances Helmstadter, from Cornell University, accepted the position of head of the International Visitors Office, to begin in August. Tara Dowling left to accept a position as assistant director of

international admissions at Boston University. Patricia Lebongo was hired as assistant to the head of the International Visitors Office, the position vacated by Ms. Dowling.

A salute to all the Information Center staff -- Kathleen Barrett, Donald Ferland, Gayle Fitzgerald, Patricia Lebongo, Terri Priest, Jean Repec, Marie Seamon, and Lillian Whelpley -- who serve with dedication, purpose, and goodwill.

MARY L. MORRISSEY

NEWS OFFICE

The MIT Press book, *Made in America* -- a disquieting evaluation of the nation's industrial health by the MIT Commission on Industrial Productivity -- was the major newsmaker of the year just past. A May 2, 1989 New York City press conference, at which the report was released, resulted in next-day national coverage and a steady drumbeat of subsequent articles, editorials, and radio and television interviews which continued into the summer. The *Made in America* project compares, in volume of coverage, with the previous year's major news story -- the successful flight of the human-powered aircraft, *Daedalus*. There is an interesting contrast between the adventuresome recreation of the *Daedalus* myth and *Made in America's* gritty, present day look at the hard decisions that must be made if the nation is to have an industrial future. Yet, both activities are very much in keeping with the spirit and mission of MIT, and the media are increasingly reflecting an understanding that MIT is multidimensional.

The news media also gave broad coverage to the return of varsity football to MIT and to President Gray's concerns over the state of science literacy in the nation.

A feature article in *Tech Talk* about the "Archives of Useless Research" maintained by the library system caught the attention of one of the national wire services and was used in many newspapers across the country. Other MIT activities that made headlines included the Leaders for Manufacturing program; MIT's solar-powered car; the discovery of a deep-ocean glow linked to a biological finding initiated by an MIT graduate student; the awarding of a seventh degree, the most ever given to an MIT student, to a Vietnamese refugee; a researcher's proposal to change the nation's electoral college system; a report by MIT astronomers that there is an atmosphere around Pluto; the proposals by researchers at MIT that a new generation of nuclear power plants be developed; and an MIT biologist's discovery of a "second" genetic code. As the year closed, a Bank of Boston economic study showed that approximately 300,000 jobs in Massachusetts alone have been created -- directly or indirectly -- by more than 600 companies founded in Massachusetts by MIT alumni. This was given extensive coverage in several Massachusetts daily newspaper

There were also national stories generated by a U.S. congressman's allegation that the Industrial Liaison Program at MIT was "selling" research to Japanese companies to the detriment of the U.S. taxpayer and by another congressman's investigative efforts into errors in scientific publications. Both congressional investigations showed some

basic misunderstandings about the unfettered exchange of scientific knowledge that characterizes the world of science and the historic interaction of MIT with industry.

Helping reporters and editors learn about activities at MIT is regular fare for the News Office. During the past year a new, unofficial function became more prevalent -- the News Office as a science news clearing house. For example, when cold fusion became a daily news topic, the News Office often got calls from writers both here and abroad asking for help in understanding the issues, not just the information on what MIT researchers were doing. Reporters, in this example and in others, often tell us that they call the MIT News Office because "If anybody knows about this, MIT will." That opinion is consistent with the hundreds of clippings we receive each year that mention MIT as a synonym for high intelligence, top engineering and scientific know-how and general inventiveness.

The staff of the News Office during 1988-89 included China Altman, assistant director-arts; Charles H. Ball, senior assistant director; Naomi Chase, in the new position of assistant director-public relations; Myles Crowley, administrative assistant to the director; Donna Coveney, assistant director-photojournalist; Robert D. Di Iorio, associate director; Mary T. Galindo, receptionist; Lynn Heinemann, senior secretary; Eugene F. Mallove, '69, assistant director-chief science writer; Joanne Miller, assistant director and editor of *Tech Talk*; and Elizabeth Thomson, assistant editor, *Tech Talk*. Naomi joined us in December. Myles joined us in February, replacing Joy King, who left in November for a position at Cambridge College.

As the year ended there was another significant change in our staff. China Altman, assistant director-arts and a member of the News Office staff since November 1982, transferred to the staff of the new Office of the Arts, effective July 1. She will continue to be the key person responsible for publicizing the arts at MIT, but her mission will be centered in the Office of the Arts where she will report to the newly appointed Associate Provost for the Arts, Professor Ellen T. Harris

Tech Talk

Our weekly newspaper, *Tech Talk*, was published 36 times for a total of 296 pages. The newspaper carried four supplements during the year: the 12-page President's Report, the 8-page Committees of the Institute, and Leaders in Manufacturing and the new Pension Plan, both 4-page supplements.

i/s, the publication of Information Systems, appeared five times in *Tech Talk*, then began independent distribution in March. The IAP timetable appeared three times in December and January. *Tech Talk* is on the verge of being capable of desktop publishing. A major step in that direction was taken in the spring when the PageMaker system was installed.

KENNETH D. CAMPBELL

Quarter Century Club

The MIT Quarter Century Club membership now totals over 2150, with each member having served the Institute for more than 25 years. At the annual meeting, which was held in March, 92 new members were inducted. The other Club functions are the picnic held in August, attended by approximately 900, and the holiday gathering in December. In late October the Club also sponsored a Dinner Dance which was held at the Cambridge Marriott. The staff of the Club provides administrative and logistical support to the Institute's United Way campaign, which, for the first time in six years, exceeded the goal set. Campaign receipts totaled \$279,286. against a target of \$270,000. The number of contributors also increased by 350.

The Institute Retirement Dinner is organized and administered by the staff for the office of the President. June ceremonies were held in Walker Memorial for 133 retiring employees and their guests.

The office also administers the MIT Activities Committee (MITAC) which organizes recreational and cultural activities for the community. Mailings are done 10 times annually to announce the various programs; last year 70 events were sponsored in addition to ongoing ticket sales for movies and museums. There is a subdivision at Lincoln Laboratory in their credit union office that handles sales which are then reported through this office.

The Club provides service and space to a chapter of the American Association of Retired Persons, Inc. (AARP) which has approximately 250 active members. They have a 16 member board which meets quarterly. Additionally, they organize 8 campus chapter meetings annually and sponsor 5 travel programs for the membership.

An extensive travel program is organized by the manager and reviewed by a committee for the alumni, retirees, and the Institute community. Last year, working with seven different companies, a total of 26 trips to various destinations worldwide was offered with most of them including lecturers from various research centers or co-sponsoring universities.

The Club was founded in 1950 and became an Institute administrative department in 1978, reporting to the Vice President in the Office of the President. There are four officers and a nine member board of directors with Daniel H. Gould serving as Chairman of the board. Full board meetings are held twice annually. Staff changes during the year included the retirement of M. Frances Daly after 45 years at the Institute, a maternity leave for Ann Brazier who returned in February with a daughter, and the addition of Donna Meuse who transferred from Lincoln Laboratory.

ANN P. BRAZIER
JAMES J. FANDEL

Office of the Secretary of the Corporation

SECRETARY OF THE CORPORATION ANNUAL REPORT

1988-1989

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

Resignations

In July, 1988, Karen L. Fulbright '79, having accepted a position as a Visiting Assistant Professor in the Department of Urban Studies and Planning, resigned her position as a member of the Corporation in accordance with the stipulations of the Bylaws. At the December meeting of the Corporation, the Membership Committee reported that the Screening Committee had proposed a nominee for election by the board to fill the remaining months of Dr. Fulbright's term. The results of that election are reported below.

In April, 1989, Donald J. Atwood '48, informed us that, having accepted appointment as Deputy Secretary of Defense, he would have to resign as a member of the MIT Corporation in accordance with DOD policy with regard to membership on outside boards. His resignation was accepted with regret by the President and the Chair of the Corporation. Mr. Atwood would have completed his 5-year term on June 30, 1989.

Completion of Service

On June 30, 1989, the following four members completed their designated terms of service: E. R. Kane '43; Margaret E. Mahoney; Robert L. Mitchell '47; Arlene Frances Roane '83.

Representatives from the Commonwealth

In April, 1989, Edward F. Hennessey, Chief Justice of the Supreme Judicial Court of the Commonwealth of Massachusetts, having reached the age of 70, retired from this post after thirteen years of distinguished service.

In June, Paul J. Liacos, was named to succeed Justice Hennessey, and as Chief Justice becomes ex officio a member of the MIT Corporation. We look forward to welcoming Justice Liacos to MIT in the coming year.

Elections

Effective December 2, 1988, Fuad U. Muhammad '87 was elected to serve the remaining months of Karen Fulbright's term until June 30, 1990.

The following nine members were elected to the Corporation for five years beginning July 1, 1989: Karen W. Arenson '70; Alexander V. d'Arbeloff '49; Jennifer L. Lund '89; Patrick J. McGovern '59; Peter M. Saint Germain '48; Richard P. Simmons '53; Mitchell W. Spellman; Raymond S. Stata '57; Dolores Wharton. (Dr. Spellman, Mr. Stata, and Mrs. Wharton have served previous terms on the Corporation.)

Two individuals were elected to Life Membership, effective July 1, 1989: Edwin C. Whitehead and T. A. Wilson '53.

Alumni Association President

On June 30, Emily V. Wade '45 completed her term of service as President of the Alumni Association and was succeeded by Harris Weinstein '56.

Transfer to Emeritus Status

Under Section 5.1 of the Bylaws, Ellmore C. Patterson, having reached the age of 75 in November, 1988, transferred to the status of Life Member Emeritus. At the December meeting of the Corporation, Dr. Saxon read a tribute to Mr. Patterson and presented him with an MIT wristwatch engraved with his name and the years of his service as a Life Member.

At his own request, John C. Haas was also transferred to Life Member Emeritus, effective July 1, 1989. Dr. Saxon paid tribute to Mr. Haas's long service to the Institute and to the Corporation at the meeting on Commencement Day. Mr. Haas was also presented with an MIT wristwatch engraved with his name and his years of service as a Life Member.

Irene du Pont, Jr., has also requested transfer to emeritus status, effective July 1, 1989. This request will be reported formally to the Corporation at its Annual Meeting on October 6.

Deaths

At the December meeting of the Corporation, the Secretary presented memorial resolutions honoring Life Member Emeritus Robert B. Semple '32, who died on November 4, 1988.

CORPORATION COMMITTEES

Executive Committee

This committee is chaired by the President and includes the Chair of the Corporation and Treasurer ex officio and seven elected members, who this year were W. Gerald Austen, Edward E. David, Jr., Joseph G. Gavin, Jr., Carl M. Mueller, Morris Tanenbaum, Edward O. Vetter, and Mary Frances Wagley. I serve as Secretary, and the Provost is invited to attend all the meetings. The Executive Committee meets regularly each month during the academic year (ten meetings). This year, the meeting on February 3, 1989, was canceled because of lack of a quorum (four out of seven non-MIT members), owing in part to inclement weather. The April meeting was held on April 4 in Geneva, Switzerland, in order to permit Executive Committee members to visit CERN and the L3 detector project under the direction of Samuel C. C. Ting, Professor of Physics and the holder of the Thomas Dudley Cabot Institute Chair. In addition to its regular agenda of reports from the senior officers and budget and salary reviews, the Executive Committee approved the revision of Corporation Bylaws and a policy statement on the nature of tenure, and discussed important, long-term issues such as MIT's international agenda and the introduction of a unified Retirement Plan for all Institute employees.

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 fiscal year under the chairmanship of Breene M. Kerr. Serving with Mr. Kerr this year were Frank T. Cary, Irene du Pont, Jr., John C.

530 Office of the Vice President

Haas, Norman B. Leventhal, Carl M. Mueller, and John S. Reed. The Institute continued its program of diversifying its assets with alternative investments in both the domestic and international markets. This has produced favorable returns and dampened volatility. On June 30, 1989, Messrs. Mueller, du Pont, and Haas, Life Members of the Corporation, completed twenty, twelve, and five years of service, respectively, as members of the Investment Committee. Each of these gentlemen, through his advice and counsel, was critical to the stewardship of the Institute's assets. Their guidance in defining an appropriate investment program to meet the current and long-term needs of the Institute has been important for both the committee and for the staff.

Membership Committee

This committee is chaired by the Chair of the Corporation, who also appoints its members. This year those serving with Dr. Saxon were E. R. Kane, Norman B. Leventhal, Rita A. O'Brien, Angus N. MacDonald, and Robert A. Swanson. (The Secretary would like to correct an error in his 1987-88 report, where it was stated that Ms. O'Brien was the first woman to serve on the Membership Committee. Dr. Mary Frances Wagley served on this committee 1975-79, and the Secretary apologizes for this oversight.)

The Membership Committee met formally twice, in October and December, for substantive discussions of membership matters. In the remaining months of the year, the members stayed in touch by telephone and mail to exchange suggestions and review nominations. Elections to membership on the Corporation are recorded earlier in this report, and changes in committee memberships will be recorded in the rosters of Standing and Visiting Committees presented to the Corporation for approval at the Annual Meeting.

Screening Committee

The Corporation Screening Committee to nominate recent graduates to membership on the Corporation was chaired this year by Arlene Frances Roane. The other members of the committee were Robert A. Charpie, Raymond S. Stata, Sarah A. L. Tabler, and Robin M. Wagner. The committee met a number of times during the 1988-89 academic year. There was an open meeting with students in November, 1988, a committee teleconference in January, a committee meeting in Cambridge in February, and two more teleconferences in late February. The five members of the committee chose a ballot of seven nominees from a group of 107 candidates from the graduates of 1987, 1988, and 1989 to elect a member from recent classes to serve on the Corporation for a five-year term. As noted above, Jennifer L. Lund '89 was the winner of the special election.

Auditing Committee

The Auditing Committee was chaired this year by Joan T. Bok and included Louis W. Cabot, J. Kenneth Jamieson, Harold J. Muckley, and DuWayne J. Peterson, Jr., as members. There were two meetings, one on October 6, 1988, and one on March 2, 1989. At each meeting Auditing Committee members were joined by representatives of the independent public accountants, Coopers & Lybrand, together with appropriate members of the administration of the Institute.

At the fall meeting the Committee discussed the Financial Statement for the Year Ended June 30, 1988, while the spring meeting was devoted to setting the scope of the audit for the year ending June 30, 1989, and reviewing the report of internal audit operations.

Advisory Committee on Shareholder Responsibility

The Advisory Committee on Shareholder Responsibility (ACSR) met twice during the spring term and conducted in addition two telephone polls to review 78 shareholder proposals on the proxies of 38 of the public corporations in which MIT is invested. The Secretary of the Committee also met twice with the Executive Committee to keep them apprised of the discussions of the ACSR in regard to the continuing proxy issue of investments in corporations with activities in South Africa. Corporation member D. Reid Weedon, Jr., continued to serve as Chair of the ACSR and Walter L. Milne as its Secretary.

Corporation Joint Advisory Committee on Institute-Wide Affairs

The Corporation Joint Advisory Committee on Institute-Wide Affairs (CJAC) held five meetings during 1988-89. Emily V. Wade, who served during 1988-89 as President of the Alumni Association, again chaired CJAC. Corporation members Samuel W. Bodman, Joseph G. Gavin, Jr., Rita A. O'Brien, Arlene Frances Roane, and D. Reid Weedon, Jr., served as members of the committee.

In March, 1989 -- following the announcements that David Saxon would retire in July, 1990, that Paul Gray would be nominated to succeed him, and that the Corporation Committee on the Presidency (CCOP) would conduct a search for a new president -- CJAC undertook its charge to gather and consider community views on the agenda and critical issues facing MIT in the 1990's, as an aid to the deliberations of CCOP. Mrs. Wade presented a progress report on behalf of CJAC at the June meeting of the Corporation.

Institute-wide interest in admissions and financial aid policies was reflected in CJAC's agenda. Professor Keith D. Stolzenbach, Chair of the Faculty Committee on Undergraduate Admissions and Financial Aid (CUAFA) and Michael C. Behnke, Director of Admissions, spoke at separate meetings of CJAC in the fall.

Professor Peter Temin kept CJAC abreast of three projects that were outgrowths of a 1987 proposal to bring South African scholars to MIT and involved Cape Town University, the Urban Foundation, and ANC Freedom College.

Once again 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.

Corporation Visiting Committees

Since their establishment in 1875, Corporation Visiting Committees have influenced the course of education and research at MIT. Following biennial visits on campus, which include meetings with faculty and students, the committees report to the Corporation and provide important advice and insights to the Corporation, the administration, and the relevant departments.

During the academic year 1988-89 eight committees held meetings:

<u>Fall 1988</u>	<u>Visiting Committee</u>	<u>Chair</u>
November 6-8	Student Affairs	D. Reid Weedon, Jr.
November 29-30	Humanities	Mary Frances Wagley
December 5-6	Electrical Engineering and Computer Science	Frank T. Cary
<u>Spring 1989</u>	<u>Visiting Committee</u>	<u>Chair</u>
February 7-8	Ocean Engineering	George P. Gardner
February 22-23	Sponsored Research	Edward O. Vetter
March 1-2	Chemical Engineering	Samuel W. Bodman
March 14-15	Economics	John K. Castle
April 26-27	Political Science	Angus N. MacDonald

All pending oral and written reports were completed for committees which met during 1987-88 (with the exception of a written report by the Libraries Visiting Committee) as well as for committees which met during 1988-89 (except for an oral report by the Chair of the Economics Visiting Committee and written reports by the Chemical Engineering and Political Science Visiting Committees).

In 1988-89, 365 persons occupied 417 slots (122 filled by Corporation members, 134 by alumni nominees, and 161 by presidential nominees) on the Institute's 25 Corporation Visiting Committees. Membership included

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20 percent women; 9 percent underrepresented minorities; 57 percent affiliated with corporations; 31 percent with academia; 5 percent with government; and 4 percent with foundations. Two members resigned during the year: Condoleezza Rice (Political Science) and Harriet W. Sheridan (Student Affairs).

Membership for 24 of the 25 Visiting Committees was replenished for 1989-90: 86 members completed their Visiting Committee service on June 30, 1989; 146 members were asked to serve an additional term; and 88 new nominees were invited to serve. Upon recommendation of the Executive Committee, the Visiting Committee for the Medical Department was discontinued. The recently established Medical Management Board includes Corporation members and will report directly to the Executive Committee of the Corporation.

MEETINGS OF THE CORPORATION

Orientation Program

On October 6, 1988, 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 with the four officers of the Corporation and Mrs. Gray. The luncheon was followed by an afternoon program of presentations by the officers of the Corporation on the structure of the trustee body and an overview of the Institute by the President. It was a very lively session with many questions and comments from the new members. Following the presentations and discussion, the new members were taken on a two-hour conducted motor tour of the campus, which included a stop at the newly renovated Stratton Student Center. At the end of the afternoon the new members and accompanying spouses were joined by the members of the Executive and Membership Committees and their spouses for a dinner at the Faculty Club.

Annual Meeting

The morning business session of the Annual Meeting on October 7, 1988, included the traditional annual reports of the President and the Treasurer as well as reports on behalf of the Auditing and the Membership Committees. In addition, the reports of the last four Visiting Committees to meet during the 1987-88 academic year were presented and approved. Following the business session, the Corporation was co-host with the Alumni Association at a luncheon at the Faculty Club, where the Association conferred 19 individual awards and 6 Presidential Citations for outstanding contributions to the Institute. It was the first time that these annual awards were presented in conjunction with a Corporation meeting, and it proved to be a very happy occasion.

After luncheon a number of Corporation members remained for a reception at the President's House honoring the Ida Green Fellows. Cecil H. Green, who established these fellowships in 1974 in honor of his wife, Life Member Emerita Ida M. Green, now deceased, spoke at this event as did several of the current fellowship recipients.

December Meeting

At the business session of the Corporation meeting on December 2, 1988, the President presented what he called a "tutorial" on the financial structure and the flow of funds at the Institute. Using a set of slides, copies of which were later attached to the minutes of the meeting, the President described the principal elements of revenue and expense that comprise the operating budget and then indicated the ways in which that operating budget relates to the Institute's assets. The President responded to questions from the members as the individual slides were shown, which resulted in a substantive discussion of the Institute's financial picture in which many members participated.

The members also enjoyed hearing, as part of the President's report, an informative presentation by Dr. Emilio Bizzi, Eugene McDermott Professor in the Brain Sciences and Human Behavior and Director of Whitaker College of Health Sciences and Technology, on the principal research directions in the Department of Brain and Cognitive Sciences at MIT.

Following the business session, members of the Faculty Council and their spouses were guests of the Corporation and their accompanying spouses at a luncheon at the Faculty Club. Professor Michael L. Dertouzos, Director of the Laboratory for Computer Science, gave a preview of the final report of the MIT Commission on Industrial Productivity, which he chaired. Following his presentation, for which he was warmly applauded, Professor Dertouzos responded to questions from the audience. The results of the Commission's study were published by the MIT Press in May, 1989.

March Meeting

At the opening session of the meeting of the Corporation on March 3, 1989, Dr. Saxon formally announced his plans to retire as Chair of the Corporation on June 30, 1990, following his 70th birthday earlier in the year. He also reported that the Executive Committee, noting that Dr. Saxon's proposed retirement date coincided with the completion of the ten-year commitment made by Dr. Gray when he was elected President in 1980, had asked Dr. Gray if he would be willing to assume the duties of the Chair at the time of Dr. Saxon's retirement. Dr. Gray had agreed to do so, and Dr. Saxon noted that at the June 5 meeting, the Corporation would be asked to vote on this Executive Committee recommendation. Following the Chairman's remarks, President Gray commented further on the proposed transition in leadership and discussed his own agenda for the remaining months of his presidential term. He indicated that he expected no change of pace and emphasized that his primary concern would be to bring to a successful conclusion the *Campaign for the future*. The Corporation received the President's remarks with applause.

Following the business session, members of the Academic Council were guests of the Corporation and their accompanying spouses at a luncheon at the Faculty Club. Professor James D. Bruce, Vice President for Information Systems, reported on the growing importance of computer networks in education and industry. His address was entitled "Viruses, Worms, Hacking, and Ethics," and in the course of his remarks Professor Bruce introduced four members of the MIT team that had worked on the problems associated with the computer virus that invaded the National Research Internet in November, 1988. It was clear from the response of the audience in the question period that followed Dr. Bruce's prepared remarks that the subject held a great deal of interest for the members.

Commencement Meeting

The Corporation held a breakfast meeting prior to the Commencement exercises on Monday, June 5, 1989. At this meeting the members elected Paul E. Gray to serve as Chair of the Corporation, effective July 1, 1990. President Gray withdrew from the meeting while the election was held and was greeted with warm applause from his colleagues when he returned to the meeting.

Following the business meeting, 26 members of the Corporation marched in the academic procession from 77 Massachusetts Avenue around the main building to the entrance to Killian Court and to the stage in front of the Richard Cockburn Maclaurin Building for the Institute's 123rd Commencement Exercises, Dr. Saxon presiding. Dr. Saxon, Dr. Gray, and Mr. Johnson marched in the Guest of Honor Division. Mrs. Wade as President of the Alumni Association was Chief Marshal, and Mr. Mitchell served as Marshal of the Corporation. Paul E. Tsongas, former Massachusetts Senator and Chairman of the Massachusetts Board of Regents of Higher Education, delivered the Commencement address, and President Gray presented the charge to the graduates. Former Presidents Stratton and Wiesner were in the audience.

REVISION OF THE BYLAWS

At the meeting of the Corporation on December 2, 1988, the Secretary, with the approval and recommendation of the Executive Committee, presented substantial revisions to the existing Bylaws of the Corporation. The review of the Bylaws and the wording of the proposed revisions had been done in close consultation with the Institute's legal counsel, Palmer & Dodge, under the direction of Jeffrey Swope. Valuable staff assistance had been provided by Lois A. Graham, Assistant to the Secretary of the Corporation.

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The proposed changes fell into several different categories. First, there were the changes made to bring the Bylaws into conformity with the existing statutes of the Commonwealth in those areas where there had been changes since the last printing of the Bylaws in 1980. Next, there were changes made to improve the clarity and consistency of the language throughout the text; changes of this nature were kept to a minimum and wherever possible the earlier text was maintained. Finally, changes were made to reflect existing accepted practices at variance with the earlier printed text. After brief discussion the Corporation voted to approve the proposed changes.

Following the approval of an additional clarifying amendment at the March meeting of the Corporation, a new edition of the Bylaws was printed as of March, 1989.

CORPORATION RECORDS

During the past year, under the direction of the Associate Secretary, Elizabeth J. Whittaker, a detailed index of the Corporation minutes covering the quarterly meetings of the board for the years 1966 through 1988 was completed. This index, which has taken four years to complete, will assist us in gaining prompt access to the records of past actions and discussions of the governing body on important issues. In the coming year Miss Whittaker will continue her efforts to ensure the preservation of Corporation records and to improve the search and indexing capabilities of the office.

SPECIAL EVENTS

Reopening of Stratton Student Center and Dedication of Catherine N. Stratton Lounge

At a festive ceremony on September 23, 1988, President Emeritus Julius A. Stratton did the honors at a ribbon-cutting event that signaled the formal reopening of the Stratton Student Center which had been closed for a year for extensive renovations. The changes throughout the building, especially in the expanded Lobdell Food Court, were warmly received by the Institute community. The previous day, September 22, a handsome new lounge on the second floor with a splendid view of Kresge Plaza, had been named in honor of Dr. Stratton's wife, Catherine N. Stratton, for her "unflagging dedication to the quality of the social and aesthetic environment" of MIT.

CONSTANTINE B. SIMONIDES

Council for the Arts

The Council for the Arts concluded its final year of independent operation in steadfast commitment to the principles by which it was founded in 1971: "to foster the arts at MIT ... to act as a catalyst for development of a broadly based, highly participatory program in the arts."

The selection of an Associate Provost for the Arts culminates a series of appointments and organizational reforms that signal the essential role of the arts within the comprehensive educational experience of MIT students. Council members will continue to participate actively as a support and advisory body to the Associate Provost and the new Office of the Arts. This office will administer those programs maintained by the Council, design and implement new initiatives, and coordinate information and publicity about creative arts activities on and off campus.

In addition to executing the programs and activities detailed below, Council staff was engaged for much of the year in preparing and facilitating this transition.

Grants Program

The Grants Committee, chaired by Bradford M. Endicott '49, received and evaluated 52 applications from students, student groups, staff and faculty, requesting a total of \$97,820. Funding was recommended for 39 projects (75 percent of those submitted), with awards totalling \$60,778 (62 percent of amount requested). Council staff reviewed 12 applications for Officer's Grants, awarding \$2,266 for the 11 approved projects. A detailed report of Grants Program activity this year is available.

One noteworthy grant was awarded to Mark Harvey, Lecturer in Music, in support of a concert series, "Jazz Expansions: An East-West Interchange", featuring emerging jazz composers and ensembles from Boston, New York and Los Angeles. To supplement the Council grant, this project was selected to be the first recipient of an award from the Roy Lamson Memorial Fund for Music. This fund was established in 1986 in honor and tribute to the late Professor Roy Lamson, dear friend and counselor to the Council, and Special Assistant for the Arts to Presidents Jerome Wiesner and Paul Gray. Administered by the Grants Program, the fund supports ambitious music projects at MIT, particularly those in harmony with Professor Lamson's own enthusiasms.

Publications

Two issues of the Council's calendar/newsletter, The Arts at MIT, were produced and distributed to a mailing list of 9,000 alumni, faculty, staff, student groups, and other individuals. The bulletin was discontinued in January, after 15 years of publication, due to budget considerations and the anticipated coordination of arts publicity with the MIT News Office.

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

Endowed Prizes and Awards

The Laya and Jerome B. Wiesner Student Art Awards were presented to Matthew McCarty '89 (Course XVI) for his achievements in theater, and to Robert Newman '89 (Course VIII) for distinction in photography. The Louis Sudler Prize in the Arts was awarded to Kenneth Goodson '89 (Course II) for excellence in music performance.

William M. Siebert, Ford Professor of Engineering, served as the Chairman of the Student Art Awards Selection Committee for the second year. He was joined on the committee by Arthur Kaledin, Professor of History, Arthur Steinberg, Professor of Anthropology/Archaeology, and Katy Kline, Curator and Acting Director of the List Visual Arts Center.

Independent Activities Period

During IAP '89, the Council sponsored an expanded version of its popular program, "ART: A User's Guide", a series of field trips to Boston-area arts performances and exhibitions. A full subscription of 45 students (with a sizable waiting list) attended five events: a performance of Russian folk dance and music by the acclaimed Moiseyev Dance Company; a Boston Philharmonic concert of work by Mahler and Richard Strauss; a production of Athol Fugard's A Lesson from Aloes by the New Repertory Theater; and special tours of the Asian Art collection at the Museum of Fine Arts and the current exhibitions at the List Visual Arts Center.

An important feature of the program is to arrange an informal, yet insightful, discussion between student participants and arts professionals. Lowell Lindgren, Professor of Music, offered illuminating remarks on the concert program; Dana Friis-Hansen, Assistant Curator at the List Center, elucidated the Contemporary artworks on display; and students exchanged questions with cast members following the Fugard play.

William L. Abramowitz Memorial Concert

The William L. Abramowitz Memorial Concert endowment provides funds to present a major performing arts event at MIT every 12-18 months. This year, the Music and Theater Arts Section agreed to organize and produce the concert. On April 28, Tony Award-winning actress and Council member Zoe Caldwell Whitehead performed "Come A-Waltzing with Me", a one-woman evening of music and dramatic readings. The concert was greeted by a capacity audience in Kresge Auditorium, as it was well-promoted through extensive coverage in the Boston media.

Boston Museum of Fine Arts (MFA) Membership Program

The MFA's University Membership Program offers free admission and discount benefits to all MIT students; ten membership cards are also provided for the daily use of MIT staff members. Participation in the program this year was made possible by special contributions from Bradford M. Endicott '49 and Bernard G. Palitz '47. Council members have funded MIT's enrollment in the program since 1980.

Institute of Contemporary Art Membership

For the second year, MIT students may obtain free admission to all exhibitions at the Institute of Contemporary Art (ICA) in Boston. This institutional membership, administered by the Council staff, has been provided through the generous contribution of Dr. Ellen Poss, member of the ICA's board of trustees.

Development Activities

Contributions from Council members and donors provided funding for all operating expenses and program activities this year. Thirty-eight Council members offered contributions averaging \$3,763 each, and 22 non-member donors bestowed an average of \$2,213 each.

A decrease in staff positions resulted in a significant reduction of projected expenses for the year. Total revenue from contributions exceeded expenditures, enabling the Council to decline a contribution from general Institute funds that had been authorized by Provost Deutch in December 1987.

Membership

At the conclusion of the year, Council membership stands at 76. Two Council members passed away during the year: Elsa Sonnabend, former Associate Director, on February 17, and Robert Semple '32 on November 4. Five members, Mary Ann Beinecke, Kenneth Germeshausen '31, Nanette Laitman, Solomon Manber '48, and Alwin Nikolais, resigned from the Council. Of the 51 members whose terms expired this year, 48 were invited to renew their commitment.

No individuals were nominated to join the Council this year.

At an Executive Committee meeting in June, it was resolved that ex officio membership status will be extended to certain senior Institute officials beginning next year: President, Provost, Associate Provost for the Arts, Dean of the School of Architecture, and Dean of the School of Humanities and Social Science.

Personnel

Helvi M. McClelland, Executive Director of the Council since September 1985, resigned her position on December 13 to relocate to Rochester, New York. Anne H. Britton served as Senior Staff Assistant from February - May.

MARK PALMGREN

List Visual Arts Center

The Committee on the Visual Arts met four times to review the List Visual Art Center (LVAC) exhibition schedule, residency program, a number of proposed acquisitions to the Permanent Collection and various strategies for expanding the connections between the contemporary art programs and the MIT community, both student and faculty/staff.

EXHIBITION PROGRAM

Eleven exhibitions were organized in the three galleries during the academic year in addition to the annual Student Loan Art Exhibition of contemporary graphics which inaugurates each season.

Nancy Spero: Works Since 1950, Hayden Gallery, October 7 - November 9, 1988. Intimate and epic-scale works addressing issues of power, gender, myth and language by the well-known New York artist.

Carl Cheng: Impressions of an Invisible Sculpture, Reference Gallery, October 7 - November 27, 1988. This California sculptor was in residence to create a full-gallery installation exploring subtle relationships between nature and mechanical technologies.

The Bear in the Marketplace: Anti-Communism and Patriotism in Recent American Advertising, Bakalar Gallery, October 7 - November 27, 1988. Boston artist Richard Bolton's visual essay analyzed the influence of superpower politics on the rhetoric and imagery of print and electronic advertisements. The installation subsequently was seen at San Francisco Camerawork.

Clockwork!, Hayden Gallery, December 16, 1988 - February 12, 1989. An eclectic selection of clocks and other timepieces by 30 contemporary artists, architects and industrial designers, illustrating inventive approaches toward measuring, manipulating, subverting or otherwise commenting upon time. Catalogue, with introductory essay by J. T. Fraser, published.

Specious Origins, Reference Gallery, December 16, 1988 - February 12, 1989. Two bodies of recent photographic work by two contemporary Spanish artists, Fontcuberta and Formiguera, whose pseudo-documentation of invented plants and animals upends the notion of scientific objectivity and photographic truth.

Recent Acquisitions, Bakalar Gallery, December 16, 1988 - February 12, 1989. A selection of important paintings, prints and photographs which have recently entered the MIT Permanent Collection, including works by Jennifer Bartlett, Gerry Bergstein, Robert Cumming, John Newman, Betye Saar, Rebecca Purdum and Donald Judd.

Felix Droese: House of Weaponlessness, Hayden Gallery, March 4 - April 23, 1989. The first US exhibition of this well-known West German artist who recreated his installation of monumental wood pieces and paper cutouts first seen as the West German representation at the 1988 International Venice Biennale. Catalogue published.

Margia Kramer: Looking at Militarism, Reference Gallery, March 4 - April 23, 1989. This multi-media documentary artist was in residence to address the extent and implications of campus investment in military research through a dramatic installation of enlarged photostatic documents, architectural pathways, a reference library and specially produced videotapes.

Beverly Pepper: An Autobiography in Form, Bakalar Gallery, March 4 - July 2, 1989. The seventh in the ongoing exhibition series exploring aspects of 20th century sculpture focusing on artists represented in the Permanent Collection. This elegant exhibition charted the origin of Pepper's forms and motifs which are culminating in her current design for the *Sol i Ombra* park in Barcelona. Guest-curated by Judith Fox. Brochure published.

Erik Bulatov: Paintings, Hayden Gallery, May 6 - July 2, 1989. The first US exhibition of the contemporary Soviet painter whose scenes from daily life often incorporate unsettling typography, light or points of view to comment obliquely on ideological conditions. The exhibition travels to The Newport Harbor Art Museum and the Renaissance Society at the University of Chicago.

James Coleman: A New Work, Reference Gallery, June 3 - July 2, 1989. A slide-tape installation with voiceover narrative created during the Irish artist's four month residency. An investigation of the nature of the photographic image and the search for meaning and identity which accompanies its creation and scrutiny.

MISCELLANEOUS HIGHLIGHTS

The List Center staff raised over \$215,000 to maintain its internationally-recognized exhibition program and continue its ambitious development. The Massachusetts Council on the Arts and Humanities provided nearly half of this external funding, making possible three unusual residency projects and three major traveling exhibitions. The National Endowment for the Arts sponsored in part two exhibitions and a residency. A variety of international government agencies and private and public foundations constituted the balance of outside funding.

The renovation and reopening of the Stratton Student Center provided the LVAC program with three fruitful opportunities. A funding consortium of the Provost's Office, Housing and Food Services, and Student Services Complex inaugurated the annual purchase of new contemporary prints and photographs for the Student Loan Program, to be housed for one year on the third floor of the Student Center before entering the lottery pool. A major drawing by John Newman was installed in the Student Center in honor of Kay Stratton's long and persuasive advocacy of the arts at MIT. Cambridge sculptor Mags Harries was selected to create a site-specific work for the building with the 1% for Art funds associated with its renovation. The piece will be developed and installed during the upcoming academic year.

Against Nature: Japanese Art in the Eighties, organized jointly by the LVAC and the Grey Art Gallery, New York University, began its seven-city tour at the San Francisco Museum of Modern Art in June. This provocative exhibition (on view at MIT in December, 1989) has received enthusiastic responses from all the major California newspapers and Time Magazine.

Assistant Curator Dana Friis-Hansen traveled to Moscow and Leningrad to discuss with appropriate artists and officials a projected exchange exhibition of American and Soviet contemporary photography.

EDUCATION PROGRAM

A wide variety of education programs and exhibition-related events were offered free of charge to the MIT community and the general public.

Informational Texts

Each exhibition was accompanied by an introductory wall text, written by a member of the curatorial staff, which presented the concepts, context, and significance of the work on view. These texts offered the uninitiated visitor an opportunity to develop a broader understanding and deeper appreciation for advanced contemporary art. Each new print from the Student Loan Art Collection on preview at the Stratton Student Center was accompanied by a didactic label discussing the artist and the issues of his or her work.

Talks, Tours, Lectures

Gallery talks at the List Visual Art Center and tours of the MIT Permanent Collection were arranged for a number of local and visiting groups, including museum member tours, adult education classes, and school and community groups. From MIT, alumni and an IAP seminar participated in discussion sessions in the galleries.

Most exhibitions were accompanied by lectures or special events. Nancy Spero and MIT Assistant Curator Dana Friis-Hansen led a walk-through gallery dialogue which examined the issues which run through her art. Carl Cheng presented a slide lecture which surveyed the development of his unique interactive art tools. In conjunction with *The Bear in the Marketplace*, (which was a cultural component of the international conference *Anticommunism and the U.S.* at Harvard University) artist Richard Bolton spoke in the gallery about his work, and later media critic Stewart Ewen, Author of *Captains of Consciousness* and *All Consuming Images: The Politics of Style*, presented a lecture entitled *Advertising/Politics*. MIT Associate Professor Harriet Ritvo, author of the recent book *The Animal Estate*, presented a gallery talk entitled *Natural History and Unnatural History* in conjunction with *Specious Origins*. Düsseldorf artist Felix Droese spoke about the central themes and political issues which motivate his artmaking. In addition to a slide lecture on her work, resident artist Margia Kramer organized a panel of esteemed experts to discuss alternatives to militarization which included, among others, Seymour Melman, Columbia University; Philip Morrison, MIT, and Pam Solo, Co-Director, Institute for Peace and International Security. Soviet expert Richard Lourie's talk *Paris in the 20s/New York in the 50s/Moscow in the 90s?* addressed issues raised by the exhibition Erik Bulatov and recent political events in the USSR. In addition to these events, MIT Curators or Guest Curators spoke about Nancy Spero, *Clockwork!*, Beverly Pepper, and Erik Bulatov in Sunday afternoon gallery talks.

Artists in Residence

The LVAC Artists-in-Residence program—essentially research and development projects—continued to offer invited artists an opportunity to draw upon the Institute's intellectual, technical, and physical resources in the realization of changing new works. Because the gallery doors are open during the course of the residency, the MIT community, the general public, and other artists are offered a view into the usually private creative process by which a work of art is formed, and interaction between the community and these distinguished visitors can develop into an enriching dialogue.

Critical Response

Extra effort was made to broaden the audience for the List Center's provocative programming, and local critics cooperated enthusiastically. WEEI Entertainment reporter Frank Dolan exclaimed "For those of you with budding scientists in the family and for those looking for the unusual place to take their children to, I've found the perfect place. It's an exhibit called 'Clockwork!'" The Patriot Ledger wrote "The MIT List Visual Arts Center has scored a coup by being the only American museum to display 'House of Weaponlessness' by the 38-year old Düsseldorf artist Felix Droese." The New York Times wrote "Clockworks is not only intriguing but—should one say it?—timely. Commissioning and collecting pieces by some 30 artists, architects, and industrial designers, the curators have filled two rooms with explorations on the meaning of keeping time." The LVAC's role in the cultural scene was summed up by David Bonetti at the Boston Phoenix: "Thank the gods for MIT's List Visual Arts Center and its intrepid staff headed by Katy Kline and Dana Friis-Hansen! Their exhibition schedule for the year is, as usual, thoughtful, provocative, and exciting. If you care about the full range of contemporary art expression, you should never miss a show at MIT."

ACQUISITIONS

The following works were acquired through either gift or purchase during the 1988-1989 academic year:

Permanent Collection

Betye Saar, *View of the World from Saturn*, 1988, mixed media assemblage. Gift of the Artist.

Robert Cumming, *The First Three Minutes, Etc.*, 1987, suite of 9 hand-colored etchings.

Donald Judd, *Untitled*, (one from a suite of 6 prints), 1980, aquatint.

David Ortins, *Untitled*, 1984, tempera and gouache on canvas. Gift of Dr. and Mrs. Leroy Lavine.

Doug Anderson, *Shiny Golden Nipple*, 1985, oil on canvas. Gift of Pere Alberch.

Christian Eckart, *Cimabue Restoration Project*, 1987, 80 hand-collaged and laminated pages from an exhibition catalog. Gift of Vera G. List.

Gyorgy Kepes, *Untitled*, 1986, oil and sand on canvas. Gift to the MIT Medical Department in memory of Bernard S. and Sophie Gould, from their family and friends.

Rebecca Purdum, *Jelly Bell*, 1988, oil on canvas mounted on board.

John Newman, *Untitled*, 1988, pastel, charcoal, pencil and collage on paper. Institute purchase in honor of Catherine N. Stratton.

Gerry Bergstein, *Untitled*, 1987, oil on paper mounted on canvas.

Eric Fischl, *Beach*, 1987, etching and aquatint. Gift of Vera G. List.

Mark Luyten, *Untitled*, 1987, watercolor on paper. Gift of Vera G. List.

Friedel Dzubas, *Untitled (MFA)*, 1981, silkscreen. Gift of Howard W. Johnson.

Robert Kabak, *Taos*, 1969, oil on canvas. Gift of Arthur P. Mattuck.

Kendra Ferguson, *To Rebuild Greenough*, 1987, collage, cut and incised paper with graphite. Gift of Michael Braunstein.

Kendra Ferguson, *Simma*, 1987, collage, cut, incised and torn paper with graphite. Gift of Michael Braunstein.

Student Loan Art Collections

Berenice Abbott, 32 black-and-white photographs, various dates, various subjects. Gift of Ronald A. Kurtz, '54.

G. Shaffer, *Postcard from Athens IV*, 1978, mezzotint with embossing (two prints received). Gift of Vera G. List.

Deborah Oropallo, *Crown Prince*, 1978, etching and aquatint. Gift of Vera G. List.

Roy Lichtenstein, *Merton of the Movies*, 1968, screenprint on foil. Gift of Vera G. List.

Walter Darby Bannard, *Spring #1*, n.d., silkscreen. Gift of Vera G. List.

Edward Stasack, *Adrift*, n.d., etching. Gift of Vera G. List.

Mary Frank, *Untitled*, n.d., lithograph. Gift of Vera G. List.

Jack Youngerman, *The New School, the 50th Year*, 1969, silkscreen poster. Gift of Vera G. List.

Jack Youngerman, *Untitled (The New School)*, 1969, silkscreen. Gift of Vera G. List.

Jim Dine, *Art*, 1968, silkscreen on photo offset. Gift of Vera G. List.

Robert Rauschenberg, *Untitled*, 1968, photo offset. Gift of Vera G. List.

Frank Stella, *Lincoln Center Festival*, 1967, offset lithograph (three prints received). Gift of Vera G. List.

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Josef Albers, *AFA Biennial Convention*, 1965, silkscreen poster. Gift of Vera G. List.

Andy Warhol, *Cow*, n.d., silkscreen (two prints received). Gift of Vera G. List.

Frank Stella, *Referendum '70*, 1970, silkscreen. Gift of Vera G. List.

Alan Shields, *Untitled*, n.d., silkscreen with machine stitching and stitch holes. Gift of Vera G. List.

Vija Celmins, *Ocean Surface - Second State*, 1985, drypoint. Purchased with funds from the Student Center Preview Program.

Vija Celmins, *Untitled (Galaxy)*, 1975, lithograph. Purchased with funds from the Student Center Preview Program.

John Baldessari, *Boat (With Figure Standing)*, 1988, photogravure and aquatint. Purchased with funds from the Student Center Preview Program.

Richard Artschwager, *Mount St. Helens*, 1981, etching. Purchased with funds from the Student Center Preview Program.

Terry Allen, *China Night*, 1985, lithograph. Purchased with funds from the Student Center Preview Program.

Judy Rifka, *On Acropolis*, 1985, color woodcut, linocut and embossing. Purchased with funds from the Student Center Preview Program.

Alan Saret, *Stars in the Sacred Ground*, 1983, portfolio of seven etchings. Purchased with funds from the Student Center Preview Program.

Vernon Fisher, *Hanging Man*, 1984, lithograph and serigraph. Purchased with funds from the Student Center Preview Program.

Edward Ruscha, *Big Dipper Over the Desert*, 1982, aquatint. Purchased with funds from the Student Center Preview Program.

Jack Goldstein, *Untitled #1* and *Untitled #2*, 1983, lithographs with silkscreen. Purchased with funds from the Student Center Preview Program.

Claes Oldenburg, *Knife Ship Superimposed on the Guggenheim Museum*, 1986, silkscreen. Purchased with funds from the Student Center Preview Program.

EXTENDED LOANS TO THE COLLECTION

Jim Dine, *Celebration 1981 (MFA)*, 1981, lithograph with silkscreen. Lent by Howard W. Johnson.

Bruce Nauman, *Untitled*, 1971, lithograph. Lent by Howard W. Johnson.

(See also previous reports.)

LOANS FROM THE PERMANENT COLLECTION

Vassilikis Takis, *Electromagnetic I*, 1962, to the Badischer Kuntsverein, Karlsruhe, West Germany, for the exhibition Otto Piene und das CAVS (Otto Piene and the CAVS), September - October 1988.

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

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

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

CONSERVATION OF THE PERMANENT COLLECTION

Sculpture conservator Steven Tatti performed work on Henry Moore, *Three-Piece Reclining Figure, Draped and Reclining Figure (Working Model for Lincoln Center Sculpture)*; Dmitri Hadzi, *Elmo*; Isaac Witkin, *Angola*; and Michael Steiner, *Niagara*.

Beverly Pepper, *Working Model for Trinity*, was treated by Dennis & Craine Associates, Cambridge.

Lester Johnson, *Profiles*, was treated by the Center for Conservation and Technical Studies, Harvard University.

Robert Kabak, *Taos*, was stretched and framed in preparation for siting in the MIT Math Department Common Room.

25 works on paper were framed or re-framed by PSG Framers, Boston, and by Old Cambridge Co., Charlestown.

**LVAC Staff
PETER A. WOLFF**

VICE PRESIDENT FOR FINANCIAL OPERATIONS

The Institute used \$5.9 million of unrestricted gifts, grants, and bequests and \$5.4 million of other funds to balance the Fiscal 1989 operating budget. These amounts excluded gifts restricted by donors and certain gifts and large bequests restricted by the Institute to preserve recognition for the donor.

The \$5.4 million of other funds included reserves and accumulated investment income from current funds. No funds functioning as endowment were used to fund the deficit.

The \$5.4 million deficit is the first year of deficit after five consecutive small surplus years in which the Institute did not have to utilize the full amount of unrestricted gifts to fund operations. In addition to the surpluses in each of the last five years, the Institute appropriated funds from current operations for the purchase of property for academic purposes. Including the surpluses, since Fiscal 1984, almost \$18 million has been committed for the necessary and critical purchases of property for academic purposes.

The major reasons for a general decline in available surplus over the last six years has been the need to provide competitive salary increases, particularly for faculty, a planned reduction in the number of undergraduate and graduate students, higher employee benefit costs, particularly for health care, increased unrestricted fund support to meet full undergraduate financial need, and a lower research base growth than in previous years, particularly compared to increases in instructional cost.

It is important to note that the deficit position in operations masks the underlying financial strength of the Institute as restricted academic funds continue to grow from endowment income, which is not spent, and as many gifts, which are increasing significantly as a result of the success of the *Campaign for the future*, flow into the current funds or restricted portion of the endowment.

The Institute designates a significant portion of unrestricted gifts as funds functioning as endowment rather than expending them to balance the operating budget. The unrestricted gifts, grants and bequests received to expendable or endowment funds during the campaign through Fiscal 1989 is approximately \$54 million. About \$22 million of these unrestricted gifts have been expended either to provide the balance between expenses and revenues in the operating budget over these years or to provide for the purchase of academic property contiguous to the campus. The remaining \$32 million has been designated as unrestricted endowment or funds functioning as endowment to strengthen the Institute's financial position for future generations of MIT faculty and students.

To eliminate growing deficits in future years, measures have been undertaken which project a reduced deficit for the current year and a return to a surplus position in Fiscal 1991 if the targets set in the budget process are achieved. These targets include cost control measures including reductions in administrative costs and a close review of program changes. Revenue enhancement targets have also been set for increased student related revenues and relief in the operating budget as a result of the Campaign, particularly in funding of faculty chairs

The correct measures to assure continued financial strength for the future of the Institute require careful planning, clear communication, and appropriate action. The continuing success of the campaign should permit the Institute to achieve a return to an operating surplus and at the same time continue the accumulation of endowment funds. We are very grateful during this period for the generous giving of our alumni and friends.

Many members of the Financial Operations area have been involved in these budget control efforts, along with their normal responsibilities. The reports that follow highlight the activities of the last year in the five major areas of Financial Operations.

A major accomplishment of the past year has been the successful first-year implementation of the development programs for Financial Operations staff.

The programs consist of three types:

A workshop on **INDIVIDUAL DEVELOPMENT PLANNING (IDP)** through a process developed, and administered this past year, by Performance Management Corporation, a consulting firm which specializes in individual job development and planning between supervisee and supervisor. Basically, the process permits the employee to outline his or her views on job content and to identify areas where further skill development may be helpful. The supervisor's input, and discussion, is brought into this process in a non-threatening way. The individuals who participated in the process last year are very enthusiastic about the program and a group of them have taken the initiative to plan orientation sessions which they will conduct to describe the process and outline some of the benefits of participating to members of the staff interested in participating in the program this year.

A series of workshops termed **FINANCIAL WORKSHOPS (FWS)** which are all-day sessions at Endicott House in Dedham, Massachusetts. Last year we conducted three workshops per term on subjects relating to job and career development. We intend to have another six workshops in the coming year and participation will be directed toward members of the support staff in Financial Operations. The workshops this year have included presentations on career and job development by Professors Schein, Carroll, Ancona, and Golden from the MIT Sloan School of Management, evaluation of managerial styles using the Myers-Briggs questionnaire conducted by Ms. Janice Williams of Janice Williams Associates, and coaching and mentoring techniques conducted by Dr. Gary Schuman of Performance Management Corporation.

A **FINANCIAL MANAGEMENT PROGRAM (FMP)** which consists of two programs a year on campus involving 14 half-day sessions describing Institute and Financial goals and administration. The sessions include presentations by Senior Institute officials and personnel in each of the major sections of the Financial Operations area. Each program has about 30-35 participants. We are continuing the FMP this year and have extended participation to include interested support staff members.

The reports of each department highlight the major activity that has occurred during the year. While they describe many of the activities, they cannot adequately express the amount of effort and careful attention of Financial Operations staff to assure that the finances of MIT continue to be effectively managed. I would like to offer my sincere appreciation and thanks to all members of the staff for their outstanding efforts over the past year.

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, 1989, the total number of women administrative staff is 89 (42%), while underrepresented minorities are 19 (9%) of the administrative staff of 213. (In 1988, these figures were 75 (39%) and 16 (8%) of 195, respectively.)

Including support and service staff members, the percentage of underrepresented minorities is 47 (12%) of a total staff of 401. (In 1988, these figures were 46 (12%) of 393.)

A statistical analysis of affirmative action results follows for each major area of Financial Operations:

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Comptroller

Comptroller's Accounting Office, Lincoln Laboratory Fiscal Office, Audit Division and Property Office

The number of women administrative staff members is 43 (39%) out of a total administrative staff of 111. (In 1988, these figures were 32 (34%) out of a total of 94.)

The number of underrepresented minorities is 21 (10%) out of a total staff of 213. (In 1988, these figures were 19 (10%) out of 195.)

Office of the Director of Finance

The number of women administrative staff members is 5 (42%) out of a total administrative staff of 12. (In 1988, these figures were 6 (50%) out of 12.)

The number of underrepresented minorities is 4 (31%) out of a total staff of 13. (In 1988, these figures were 2 (15%) out of 13.)

Office of Purchasing and Stores

The number of women administrative staff members is 5 (21%) out of a total administrative staff of 24. (In 1988, these figures were 4 (18%) out of 22.)

The number of underrepresented minorities is 12 (15%) out of a total staff of 78. (In 1988, these figures were 10 (14%) out of 77.)

Office of Registration and Student Financial Services

The number of women administrative staff members is 26 (65%) out of a total administrative staff of 40. (In 1988, these figures were 23 (59%) out of 39.)

The number of underrepresented minorities is 13 (19%) out of a total staff of 69. (In 1988, these figures were 13 (19%) out of 67.)

Office of Sponsored Programs

The number of women administrative staff members is 9 (45%) out of a total administrative staff of 20. (In 1988, these figures were 9 (45%) out of 20.)

The number of underrepresented minorities is 2 (6%) out of a total staff of 32. (In 1988, these figures were 2 (6%) out of 32.)

JAMES J. CULLITON

Office of the Comptroller

THE COMPTROLLER'S ACCOUNTING OFFICE - CAMBRIDGE

Payroll

Efforts continued to complete the upgrade of the Payroll System to current computer technology. The Staff Payroll Distribution/Accounting function was successfully implemented in December 1988, and a few months later related fiscal year conversion procedures were also completed. Comprehensive modifications were made to the gross-to-net process of the Payroll System as part of the new Unified Pension Plan. A new tax reporting subsystem for foreign nationals' source income was designed and implemented as required by earlier Federal Government regulations. Modifications were made to the Form W-2 tax reporting subsystem to accommodate new regulations and to provide for an earlier production date capability.

Accounts Payable

During the past year the new Accounts Payable System was successfully dispersed to the Laboratory for Nuclear Science as a beta site. This system, in conjunction with the new Purchasing System, will now allow certain departments to issue purchase orders, receive goods, and pay invoices. This system will be offered to other departments during the coming year.

Chart of Accounts

The Chart of Accounts was successfully dispersed to the Office of Sponsored Programs (OSP). This interactive computer system will now allow OSP personnel to electronically change Chart information and send hard copies of their changes throughout the Institute. This computerized system replaces a labor-intensive, handwritten worksheet-to-typewriter-to-keypunch operation. Longer term benefits of this system are expected to be a more current and more accurate Chart of Accounts and improved control processes.

Benefits Accounting

With the consolidation and changes to the MIT Pension Plans effective July 1, 1989, the following actions were taken: the Pension Accounting System data base was expanded to handle the new data required by the revised plan; data was extracted from personnel files and the Retirement Plan for Employees to add to the Pension Accounting System data base for all employees eligible for the new plan; specifications were drawn for changes needed within the Campus and Lincoln Payroll and Personnel Systems to generate contributions and eligibility information (testing is underway); program specifications, changes, and testing are proceeding on portions of the Pension Accounting System which are run monthly; designed and planned for data requirements and interfaces for projection and benefit calculation routines being developed by TPF&C; and computer equipment has been updated to provide for a local area network which is being established between the Benefits Accounting Office, the Personnel Benefits Office, and the Comptroller's Accounting Office Data Processing Section.

THE LINCOLN LABORATORY FISCAL OFFICE

The Lincoln Fiscal Office is continuing to enhance the Automated Purchasing System at Lincoln Laboratory which was introduced in 1988. Significant benefits have been the

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reduced time to process requisitions, elimination of a backlog in the receiving room, and enhanced tracking of requisitions and purchase orders.

Lincoln Fiscal Office is also developing an on-line Cash Transaction System in the Cashier's Office to be implemented in the fall of 1989. This will aid the Cashier's Office in recording each transaction as it happens, reconciling at the end of each day, producing deposits, and journalizing all accounting transactions.

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 8,700 newly acquired items of moveable equipment were identified and tagged. The biennial inventory of items of moveable equipment was continued. One hundred ninety two final inventories were completed and submitted to the sponsor as part of closing out the contracts, grants, and agreements. There were 599 financial reports prepared and submitted to various government agencies. Monthly reconciliation of the Accounting Office records with the Property Office records continued with very positive results. Forty nine thousand dollars (original acquisition cost) of excess government equipment was acquired. Seven hundred eighty nine items of equipment with an acquisition value of \$705,000 were transferred between MIT departments as part of a reutilization program. Equipment, unneeded or unuseable by the MIT community, was sold for \$386,000 providing funds for replacement equipment. Most of the equipment available for reutilization or sale continued to be displayed at the MIT Equipment Exchange.

Phase I of a new Property System has been completed with the conversion from the old system to an Ingres-based system running on a MICROVAX Model 3500. A system needs document, which will be the basis for Phase II of the new system, has been completed by Administrative Systems Development.

The Society for Property Administrators, which is administered by the Property Office, conducted a three-day Property Management Conference in Albuquerque, New Mexico, in November 1988. More than 150 attendees from the United States and Canada were present at the conference.

THE AUDIT DIVISION

The Audit Division's role, to give reasonable assurance that management policies and procedures are being adhered to as intended, that adequate internal controls are being maintained, and that assets are properly safeguarded, continues to be strengthened. Over the past year, the Audit Division has undergone significant change in its overall audit approach while remaining responsive to requests for audit services from various entities throughout the Institute.

Internally, a more structured methodology has been adopted and resources are being allocated in the most effective manner by selecting areas for audit based upon analysis of the risk involved. Attention has focused on more complex areas where control weaknesses could have a significant adverse impact on the Institute. To this end, several management business systems reviews have been undertaken to encompass gaining an understanding of entire business functions and determining the effectiveness and efficiency of various systems and procedures.

Data processing audit coverage continued to be a major area of audit emphasis, reflecting increased Institute awareness of the necessity for protection of computer data and hardware.

Audit effort for Lincoln Laboratory has increased significantly at the request of Laboratory management and is warranted by its high research volume. Initial audit efforts involved the review of Laboratory computer facilities and the payroll function. Additional planned reviews include construction accounting, inventory control, and procurement procedures.

The Audit Division accomplished a record number of departmental reviews over the past year. The scope of these reviews focuses on key accounting controls and compliance requirements. Over 50 departments, laboratories and centers were evaluated.

Personnel Changes

The following staff changes occurred within the Comptroller's Office during the past year:

New Appointments

Khaled Y. Abou-Zaki
Auditor II

John J. Bentley
Analyst/Programmer II

William B. Bumpus
Analyst/Programmer III

Debra E. Cobb
Senior Staff Accountant

Claude B. Desrosiers
Consultant II

Mary T. Donovan
Analyst/Programmer II

R. Thomas Eirich, Jr.
Computing Trainer

Carolyn A. Fuller
Analyst/Programmer III

Suzanna Garfunkel
Analyst/Programmer II

Patricia J. Gilardi
Senior Analyst/Programmer

Elizabeth A. Greene
Analyst/Programmer III

Promotional Appointments

Jo-Anne M. Chute
Property Auditor

Deborah A. Gibson
Senior Staff Accountant

Retirements

Robert W. McQuillan
Assistant to the Comptroller
32 years' service

Robert M. Sullivan
Assistant Accounting Officer
26 years' service

Robert D. Taylor
Assistant Director
38 years' service

Resignations

William N. Cataldo
Senior Staff Accountant

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Suna Gulen
Analyst/Programmer III

David M. Hardy
Analyst/Programmer II

William F. Huxley
Technical Supervisor

William S. Irving
Audit Manager

Robert W. McQuillan
Assistant to the Comptroller

John M. O'Connor
Auditor I

Judith A. Quimby
Staff Accountant

Edward S. Roepe II
Senior Analyst/Programmer

Susan R. Rice
Senior Analyst/Programmer

William H. Simpson
Technical Supervisor

Clare E. Stanley
Analyst/Programmer II

Betty J. Trammell
Accounting Officer

Kimball C. Warren
Consultant I

Lynda B. Wellen
Auditor I

Eugenia L. Gordon
Senior Analyst/Programmer

Lloyd M. Harte, Jr.
Auditor I

Sheriefa Siers
Senior Analyst/Programmer

David J. Tenen
Analyst/Programmer II

Promotions

Denise E. Blacker
Senior Staff Accountant

Robert P. Casey
Senior Staff Accountant

Robert N. Clark, Jr.
Auditor I

William T. Conley
Assistant Director

Mary Ann Donofrio
Senior Accounting Officer

Margaret E. Fahey
Accounting Officer

Eleanor C. Forsberg
Accounting Officer

Michael J. Glynn
Analyst/Programmer II

Suna Gulen
Senior Analyst/Programmer

Alan E. Harrington
Senior Accounting Officer

Anastasia J. Janus
Assistant Accounting Officer

Elizabeth A. Kelley
Senior Staff Accountant

Kevin J. Milligan
Assistant Director

Elizabeth C. Nelligan
Accounting Officer

Guy L. Spina
Assistant Accounting Officer

Maria Tantoulos
Senior Staff Accountant

Scott T. Thornhill
Senior Staff Accountant

Wayne T. Turner
Assistant Accounting Officer

PHILIP J. KEOHAN

Office of Financial Planning and Management

Fiscal 1989 Results of Operations

Total operating expenses for the year were \$947.2 million - down 0.4 percent from the previous year. The decrease results primarily from the reduction of subcontracts at the Lincoln Laboratory which dropped from \$82.4 million in 1987-1988 to \$48.6 million in 1988-1989. In addition, the Institute adopted depreciation accounting for buildings and equipment which further masked the growth between the two fiscal years. Net of these changes, the programs of the Institute, as expressed in financial terms of total operating expenditures, grew by 4.8 percent. In comparison inflation, as measured by the consumer price index for all urban workers, grew by 4.7 percent.

After five years of surpluses the Institute recorded a deficit of \$5.4 million which was some \$0.9 million less than the budgeted deficit of \$6.3 million. To put the current year's deficit in perspective, it should be noted that the deficit equals roughly one third of the amount set aside from unrestricted operating revenues during the previous five years for use to acquire, construct, and renovate major facilities. In addition, the principal balance of unrestricted funds functioning as an endowment grew from \$31.0 million in 1982-1983 (the last year the Institute recorded a deficit) to \$68.9 million in 1988-1989.

Surpluses and deficits need to be viewed in a historical perspective and in comparison to financial changes in reserves and endowment. While they may be small in comparison to total operating expenses (this year's deficit at \$5.4 million was only 0.6 percent of total operating expenses), they nonetheless provide an insight into future operations and the flexibility the Institute will have in responding to new initiatives.

Financial Planning

This year's deficit is the result of financial forces underway for the last several years. First, is the relatively flat growth rate of the modified total direct cost base for campus research (MTDC) when compared with the growth rate for instruction and unsponsored research. During fiscal 1989 the MTDC base grew by 4.6 percent and instruction and unsponsored research by 6.4 percent. This differential growth rate reallocates academic administration and support costs from sponsors to unrestricted funds. Second, fiscal 1989 was the third and final year of a planned reduction in undergraduate enrollment. Third, is the continued need to increase salaries at a rate faster than inflation.

When you combine these expense pressures with a desire to minimize the increase in tuition and self-help rates you create a condition of imbalanced budgets, that must be made up by other revenues sources.

Capital Budgeting

After several years of modest activity in the major renovation of facilities, acquisition of land, and construction of new facilities, the capital budget increased from \$60.5 million at the beginning of the year to \$189.6 million at the end of the year. The active project list includes a new Biology building on Ames Street, a graduate student residence on Albany Street, the addition of the South Hall Ring at the Bates Linear Accelerator, an addition to the Rotch Library, and the acquisition and renovation of 38 Memorial Drive. In addition the Institute substantially completed renovations at the Faculty Club, the Stratton Student Center, and placed in operation its new telecommunications system.

Systems Support for the Budget

During late fall the first phase of the new Budget Entry, Edit, and Review system became fully operational. The new system is based on a database management software resident on a micro computer that is linked to individual work stations. The system sends budget data to the mainframe accounting system and, in return, receives chart of account and actual information from the accounting system.

During the year the "global budgeting" module was completed. This application allows the automatic increase of an object code in all accounts (such as faculty salaries) to be increased by a constant percentage. Also completed during the

year was MITBUD for use on IBM or compatible personal computers. MITBUD is a budgeting tool for developing department budgets and allows for the electronic input of those budgets to the BEERS system. As MITBUD came on line in the fall, the diversity of departmental budgeting styles and the difficulty of running a software house became apparent.

The power of the system to track budget changes, to analyze data, and to make special reports became even more apparent as the year progressed. The need to find the time to enhance and add new modules is also apparent, as is the need to resist adjusting the system to each short-lived exception that others might want.

Personnel and Organization

Robert G. Gulian joined the staff as an Analyst Programmer at the beginning of the year. Bob's addition brings the system staff to two full time employees.

In late fall, Mary E. Gibson, who has been a colleague since 1983, left to become the Administrative Officer for Project Athena. In the spring Gregory R. Arsenault resigned to take a position in private industry working on the type of computer systems he so ably developed for the office. At the end of the year Richard M. Hill, who joined the staff in 1979, will become Assistant Dean for Finance in the School of Science. Rick had overall responsibility for the budget system design and implementation. While it is a compliment to have other MIT departments and private industry seek out your people to fill their critical needs, it comes at some cost. All three were valued members of our community and their loss will provide a void that will require several years to fill.

In the spring Gregory Thompson joined the staff as an Assistant Budget Officer and at the end of the year Wai-Ming Li joined us as an Analyst Programmer. These two will form the nucleus for rebuilding the staff.

JOHN A. CURRIE

Office of Purchasing and Stores

Major projects accomplished or initiated this year include:

- 1) Development commenced in March of a universally available, on-line, and interactive electronic requisitioning system with three integrated parts:
 - Electronic Requisitioning. Users will be able to create, store, display, print, and forward requisitions to account approvers, review offices, purchasing offices, and the Office of Laboratory Supplies.
 - Electronic Speed Orders. A department (laboratory and center) awarded purchase order system to enable the more timely acquisition of low dollar value standard supplies and routine services by end users. If the electronic requisition meets predefined criteria, the system, if the user desires, will issue a purchase order number immediately, which the user can promptly relay to the vendor.
 - Access to Purchasing and Accounts Payable System Information. Users will be able to get up-to-the-moment information on the status of requisitions, purchase orders, and invoices within the Purchasing and Accounts Payable system.

A limited function prototype of the system will be installed for test purposes using "live" requisitions and purchase orders in July of the coming year, initially in two user departments. Additional user locations will be added throughout the coming year.

With the knowledge and experience to be gained from use of the prototype system, approval and funding will be sought to proceed with the development of a full functionality system, which could be available by summer 1990.

- 2) A fully automated, on-line and interactive Inventory Management System became operational in the Office of Laboratory Supplies (OLS) in December. The major features of this system include order entry and processing, billing of internal accounts, materials handling, perpetual inventory control, inventory management and replenishment, and sales analysis. This system has substantially modernized and expedited processing and materials handling, distribution, and delivery of items stocked by OLS, and has and will continue to contribute to improved service at lower cost of operations. OLS receives, processes, and fills in excess of 100,000 requisitions per year in support of community needs.

Electronic requisitioning to the OLS will be made available to the community, as an integral part of the prototype system discussed above, in the fall of the coming year.

- 3) A Digital Equipment Corporation MicroVAX 3600 computer was purchased to provide Institute-wide access to the electronic requisitioning, electronic speed order, and information access systems discussed above. The acquisition of this computer was necessitated by performance, security, and system access considerations due to the required open system design needed to provide Institute-wide access, and to maintain existing Purchasing and Accounts Payable application system security.
- 4) Participation commenced with the Environmental Medical Service and the Safety Office in the investigation, planning, and development of (i) controls, reporting, and tracking mechanisms for hazardous substance purchases, and (ii) purchasing methods and procedures to ensure compliance with Federal, State and local government regulations and MIT policies regarding the management and control of hazardous substances. This effort will continue during the coming year and is expected to result in the centralization of chemicals purchasing, receiving, and delivery functions at the Office of Laboratory Supplies, and the development and implementation of appropriate automation to enable production of accurate reports to facilitate the tracking of hazardous substances.

General Purchasing Office

Purchasing activity for the year continued at the previous year's level. Of a total 84,000 purchase orders issued by all on-campus purchasing agencies, the General Purchasing Office (GPO) processed and issued 57,400 or 68 percent of the total.

Since a primary responsibility of this office is the purchase of required goods and services at lowest practicable prices, major emphasis continued to be placed on negotiating discount agreements and other favorable pricing arrangements with suppliers.

In an effort to ensure compliance with the Institute's new policy on break-resistant containers for the transport and storage of chemicals, the GPO notified 1,300 chemicals suppliers of the new policy, and instructed that break-resistant containers, when available, were to be utilized for chemicals shipped to MIT. In addition, buying agents commenced specifying break-resistant containers when ordering chemicals.

Office of Laboratory Supplies

Combined sales of office and laboratory items and furniture and furnishings increased 16 percent over the previous year. Sales of office and laboratory items increased 9 percent and sales of furniture and furnishings increased 27 percent.

Established systems for receiving, storage, and delivery continued to be utilized to support the Microcomputer Center's personal computer resale programs.

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In compliance with the Institute's new policy on break-resistant containers for the transport and storage of chemicals, programs were instituted (i) for purchasing stock chemicals in break-resistant containers, whenever possible, and (ii) for dispensing chemicals in breakable containers only when the customer has or purchases (from OLS) an approved secondary container in which to place the chemical for transporting before leaving the stockroom.

Minority and Woman-Owned Business Purchasing Programs

Business placed Institute-wide under these affirmative action procurement programs resulted in the award of over \$13.0 million to minority and woman-owned business concerns. Over \$5.0 million was awarded to 280 minority businesses and over \$8.0 million was awarded to 650 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. The number of active Subcontracting Plans under Institute Federal contracts has grown from 25 in 1980 to 70 this year, necessitating the submission of over 200 separate reports of accomplishments annually to Federal sponsors. Additionally, in order to provide guidance and assistance to principal investigators, over 300 internal progress reports are issued annually.

An automated Federal Subcontracting Plan Reporting System (subsystem) was developed and implemented to replace the labor intensive aspects of the manual preparation of reports to Federal sponsors.

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 renovation of the office space was completed in a highly successful manner; Professor Patrice Derrington of the Laboratory for Architecture and Planning used this project as a case study on renovation for her summer course. Also, a video tape entitled "Repaying Your Student Loans: A Decade of Working Together" was developed and produced by the staff in conjunction with the Center for Advanced Engineering Study, and has become an important and integral part of the federally-required "exit interview" counselling process.

In the Registrar's Office, the business analysis undertaken with the help of the Exeter Group is essentially complete. The recommendation is to replace the current system with a new student system that is easier/less costly to maintain, that can be run in an on-line interactive mode during the day, that has a simpler file structure (taking advantage of the modern database architecture and capabilities), and that runs on hardware dedicated to the system. A request was submitted for funds to proceed with the first phase in the development of a new Student Information System--to undertake an analysis of the system specifications and total costs, for review next spring before proceeding with full system development.

In the Student Financial Aid Office, we believe we now have confirmation of the re-establishment of a trend toward increasing numbers of needy students in our undergraduate population. Until recently, over a five year period, we have reported a reduction in this number chiefly due to the cut in national income-taxing rates making more discretionary income available to our parents. Although this increasingly needy student body resulted in more grants to MIT from federal programs last year, this increase has not kept pace with our needs and the federal participation percentage figure dropped to 13 percent, the lowest since the early 1960's.

These accomplishments are discussed in further detail, and others mentioned, in the individual reports that follow from the Bursar, the Registrar, and the Director of Student Financial Aid.

JACK H. FRAILEY, Director

BURSAR'S OFFICE

Overview

Major achievements in the Bursar's Office were:

•**Staffing**-- We created the position of Financial Officer and filled that position six months prior to the retirement of the Associate Bursar/Executive Officer, to allow training time for a smooth transition of financial responsibilities.

•**Federal Regulations**-- In compliance with extensive new regulations governing federal loan programs, we reviewed and revised all our loan notes, did additional loan counselling, and produced and used our first videotape. We accomplished all this without an increase in staff. We have started to gain national attention in this area because many universities do not yet know how to implement the new regulations. We showed our videotape at the National Association for Student Financial Aid Administrators (NASFAA) national conference and at the Massachusetts Higher Education Assistance Corporation (MHEAC) lenders conference. It received great reviews and requests for copies to be used as a model, despite the fact that the content is specific to MIT.

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•**Loan System**-- We did a series of demonstrations of our new loan system (serviced by First Wachovia Student Financial Services of Winston-Salem, NC) for senior MIT management and received positive feedback, including the comment that this represents the first time the Institute has successfully taken an application outside to a service bureau, and that the success here will lead MIT to look for other opportunities. An article about the student loan system conversion was written for and accepted by Business Officer magazine, a publication of the National Association of College and University Business Officers (NACUBO).

•**Renovation**-- The renovation of our office space was completed and was highly successful. This has enhanced our professional image and created a more functional work environment. A recent student editorial in The Tech said, "The redesign of the Bursar's Office restructured the furniture to express the purpose of the facility. The room now focuses the attention of the occupants on the services they provide, with an accompanying improvement in attitude." Professor Patrice Derrington of the Laboratory for Architecture and Planning used the Bursar's Office as a case study on renovation for her summer course.

Student Services

We continued our efforts to improve service to students. We clarified and strengthened meal plan billing procedures; coordinated the schedule of mailings to incoming students from all student service offices; initiated Institute-wide consideration of the "special student" and "re-admitted student" populations; and initiated improved procedures.

Student tuition, fees, and other charges totaling \$145,651,887 were billed, an increase of 6.3 percent from last year. The amount collected as a percentage of the amount billed was 99.1 percent. Servicing the 18,217 student accounts required 212,909 transactions to the student accounts receivable system. Income from late payment fees was \$109,083 and income from finance charges was \$192,529.

MIT's Parent Loan Plan (PLP), established in 1977, is an important source of funding for 339 families with 203 active PLP accounts and approximately 52 new borrowers this year. A total of \$1,831,249 was disbursed during the year and \$2,270,994 in principal was collected. The PLP receivable at the end of the fiscal year was \$2,462,124. The default rate for the Parent Loan Plan (calculated as of May 31, 1989 using the formula for NDSL/Perkins Loans) is 1.02 percent.

The total student population supported by a sponsor (government, military, etc.) for the academic year 1988-89 was 702 students, representing total billings to sponsors of \$9,399,818.

Alumni Services

A videotape entitled "Repaying Your Student Loans: A Decade of Working Together" was developed and produced by our staff and the MIT Center for Advanced Engineering Study. The video was shown to all student loan recipients who received a degree in June and is part of the federally-required "exit interview" counselling session. In compliance with new regulations, student loan information, including repayment information, was mailed to all borrowers along with the loan note.

All student loan notes were reviewed by MIT's legal counsel and revised to comply with appropriate regulations.

Student loans receivable totaled \$41,635,257 at fiscal year end. These notes were funded by \$15,981,148 of MIT loan funds established by friends and alumni of the Institute; \$20,185,440 of federal funds in support of the Perkins (formerly the National Direct Student) Loan Program; \$51,856 of federal funds borrowed to support a portion of our contribution to the Perkins Loan Program; \$2,316,813 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 2.2 percent in 1988 (compared to 1.9 percent in 1987); the national default rate for that program decreased from 8.0 percent in 1987 to 7.3 percent in 1988. MIT's default rate on Stafford Student Loans (formerly called GSL's and FISL's) was 2.4 percent in 1988 (compared to 2.0 percent in 1987); the corresponding national default rate increased from 13.1 percent in 1987 to 13.3 percent in 1988.

Accounting and Information Systems

Two major programming tasks were completed this year: putting new loans onto the First Wachovia system by tape transfer from the MIT student financial aid system (saving us from having to fill out a paper form for each new loan and preventing attendant data entry errors); and programming the MIT student system for "separation date," to accurately transfer to the First Wachovia system a student's registration status. "Separation date" is one of the most important data elements on that loan system because it is the "trigger" that starts a lot of federally-regulated activity related to a loan going into repayment.

In addition to these two major projects, we automated many of our accounting and cash reconciliation procedures; and developed a procedure to ensure that a payment made by a student at our office would show up on his/her account the next day. We converted numerous production, retrieval, and report programs on the SAR system from VS1 to CMS batch and improved documentation, due to MIT's decision to phase out VS1. We also implemented form printing on the Xerox 9700 machine, which saves on the cost of pre-printed forms and eliminates the necessity to monitor form stock and to thread special forms into the printer.

Staff Notes

Carolyn A. Bunker joined our staff as Financial Officer in January. She came from Boston University where she was Assistant Comptroller, Tax Reporting and Consolidations.

Sandra Chauncey joined our staff as Assistant Bursar/Loan Collection in January. She came from Boston University where she was Assistant Manager, Student Loans.

Florent Lebongo joined our staff as Assistant to the Bursar/Student Services in June. He came from the Ministry of Finance in Cameroon where he was Research Division Director.

Maurice L. Linton, Assistant to the Bursar/Student Services, left in April to become Administrative Officer in MIT's Department of Political Science, a significant promotion for him.

Sue H. McKinley, Assistant to the Bursar/Accounting and Control, left in November to become a consultant.

John R. Rogers, Associate Bursar/Executive Officer, retired in June after 29 years of service to MIT.

SHIRLEY M. PICARDI, Bursar

REGISTRAR'S OFFICE

Enrollment

In 1988-89 student enrollment was 9,500, compared with 9,565 in 1987-88. This total was comprised of 4,325 undergraduates (compared with 4,377 the previous year), and 5,175 graduate students (compared with 5,188 the previous year). Undergraduate enrollment is expected to grow over the next several years as a result of the Institute's decision to increase the freshman class size from the current 1,000 to about 1,050 beginning

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September 1989. The International student population was 1,964, representing eight percent of the undergraduate and 31 percent of the graduate populations. These students were citizens of 96 countries. Students with permanent residence status are included with US citizens.

In 1988-89, there were 2,429 women students (1,412 undergraduate and 1,017 graduate) at the Institute, compared with 2,389 (1,384 undergraduate and 1,005 graduate) in 1987-88. In September 1988, 338 first-year women entered MIT, representing 34 percent of the freshman class.

In 1988-89, there were, as self-reported by students, 1,637 minority students (1,331 undergraduate and 306 graduate) at the Institute, compared with 1,475 (1,236 undergraduate and 239 graduate) in 1987-88. Minority students included 332 Black Americans (non-Hispanic), 30 Native Americans, 353 Hispanic Americans, and 922 Asian Americans. The first-year class entering in September 1988 included 374 minority students, representing 38 percent of the class.

Degrees Awarded

Degrees awarded by the Institute in 1988-89 included 1,193 bachelor's degrees, 1,068 master's degrees, 41 engineer's degrees, and 492 doctoral degrees -- a total of 2,794 (compared with 2,771 in 1987-88).

Tabular Presentation

Most of the above 1988-89 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: assisting the work of various Faculty Committees (e.g., in developing: evening exam policy, proposals to address flexibility and Pass/No Record grading in the freshman year, policy regarding changes in the time of final exams after the schedule has been published, and codification of policies and streamlined procedures for departments to submit proposals for new/revised subjects); fulfilling a wide variety of requests for information and statistics; undertaking a complex set of requests for linking and tying recitation sections between freshman calculus and physics, and giving freshmen choice in recitation style; providing students with a much improved Class Schedule Card; including grades received by MIT undergraduates at Harvard College on the MIT transcript; developing procedures to make certain that grade information for MIT students on the degree list taking subjects at Harvard arrives at MIT before degree decisions are made; successfully implementing policies to handle the Registration Day conflict with Rosh Hashanah; presenting a calendar proposal to the CUP and FPC to address the serious compression of the academic calendar at the end of spring term; rewriting all messages on grade sheets to clarify grade definitions and faculty responsibilities for submitting grades; revising the Change of Course form and procedures to make the process more effective for departments; developing a means for students to provide the phonetic pronunciation of their names for Commencement; providing for the approval and recognition of the new HASS Minors on diplomas and the Commencement book; and making substantial progress in revising the undergraduate degree audit to reflect the changes in the undergraduate degree requirements effective with the Class of 1990 (counting the 17-subject Institute Requirements as "subjects," and auditing the provision that one Science Distribution subject must be both outside the student's department and departmental degree program).

•Add several major subsystems to the Student Information System: developing a new database system on the PC network for updating catalogue subject descriptions, monitoring the approval process, and disseminating subject and curricular information to various offices/departments; developing a major program that

specifies students' Separation Dates from MIT (to assist with loan and financial aid management); and completing the specifications and programming to develop on the PC network the capability to do Commencement degrees and the Commencement Book processing.

•Strengthen effectiveness in administrative procedures and office operations: strengthening the procedures for not allowing students to Register who are on Financial Hold, including writing directly to each student; automating the process of entering the Last College Attended by graduate students on their Permanent Record, and discontinuing the inclusion of the previous degree received and date, since this information is not directly verified; maintaining a system to periodically pass Directory Information to the Alumni Association for the new Parents' Program; making progress in rewriting GASP into C language and in developing documentation on desirable enhancements to the scheduling system; revising job descriptions of all staff and support staff positions in the Registrar's Office to reflect the changes in responsibilities that have occurred over the years, and completing a review by the Personnel Office of all positions for both content (classification level) and salary equity; examining and improving the space utilization and physical working environment in the Registrar's Office, and submitting a proposal for completely renovating the Registrar's Office space or for moving the entire Registrar's Office back to the main building; streamlining procedures for dealing with missing grades on permanent records; and revising all Registration instructions and forms, and degree applications, to clarify the process and reduce costs.

•Strengthen and update the Student Information System: completing, with the help of the Exeter Group, a comprehensive assessment of the capabilities and needs of the computer system operated by the Registrar's Office in order to ascertain the information and systems needs of users/potential users and how effectively the current system is set for meeting them. The recommendation is to replace the current system with a new student system that is easier/less costly to maintain, that can be run in an on-line interactive mode during the day, that has a simpler file structure (taking advantage of modern database architecture and capabilities), and that runs on hardware dedicated to the system. A new system is essential for addressing current problems with the student system and expanding the types and levels of service that are expected by the academic community at MIT. A request was submitted for funds to proceed with the first phase in the development of a new Student System -- to undertake an analysis of the system specifications and total costs, for review next spring before proceeding with full system development. The proposal is to continue running under VS1 so that resources can then be directed toward the development and implementation of the new student system over a three- to four-year period. If development of a new system is delayed, then VS1 conversion must proceed -- which appears to be both expensive and risky -- and once finished, all we have is a converted old system. Efforts have been initiated to document current operating procedures and functions, pending approval of the proposal to go forward.

Important Issues on the Agenda

•Move forward with the development of a new student system (secure funding and undertake the detailed analysis of specifications and costs, including documentation of the functionality and operating procedures of the current system; establish structure for user input and management oversight; define system architecture).

•Strengthen the academic research capabilities in the Registrar's Office in support of the Institute's educational programs to address an important institutional need that is not currently being met.

•Continue to develop various ways of passing data electronically from the Registrar's Office to faculty and departmental offices and vice versa; develop electronic ways to assist departments in conducting audits of the completion of students' departmental degree program requirements.

•Develop enhancements that make the GASP scheduling system more flexible and responsive to faculty and departmental needs. Establish a computerized room scheduling book on the PC network. Strengthen special scheduling efforts in support of the freshman year.

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- Work with the Planning Office and Dean for Undergraduate Education on an extensive renovation program for classroom/lecture facilities at MIT.
- Secure space in the main building for the Registrar's Office so that we can more effectively support students, faculty, and the educational activities at MIT. Continue to strengthen the Office's current physical working environment.
- Continue to streamline the audit of the new undergraduate degree requirements. Implement the changes made by the Faculty in Pass/Fail grading. Develop a more formal procedure for doing IAP Registration.
- Develop an electronic certification/verification process so that students and alumni can get faster, more complete official letters providing information about their attendance at MIT.
- Develop with the Institute Archivist a clear written archival policy for the retention of student records at MIT. Complete a disaster recovery plan for the Student Information System.

Staff Notes

Rogers O'Neill joined the office as Manager of the Student Information System and Associate Registrar, and JoAnne Stevenson joined the staff as Analyst Programmer III.

DAVID S. WILEY, Registrar

STUDENT FINANCIAL AID OFFICE

The Valley Traversed

The highlight in financial aid this year was not national developments, but confirmation of a significant turnaround here at the Institute. We have reported, over some five years now, a reduction in the number of needy students receiving aid, followed by a recovery in that number. That valley, in one of our most vital statistics, seems now to have been fully crossed; and we face now a steady annual increase, boosted by three factors. (a) The original cause of the decrease -- the cut in national income-taxing rates, is behind us, and (if anything) we would expect the next few years to see increases in taxing rates. (b) MIT's costs, reflected in tuition rate, are not diminishing, but continue to rise faster than inflation. (c) The percentage of the freshman class that come from the lowest national income quartile showed a noticeable increase both last year and this, indicating that (tax-rate effects aside) we are seeing a needier population enrolling.

While this increase is to be applauded because it tends to move the Institute's student body that much closer to the national economic distribution, it is bound to have important implications on the Institute's budgeting process. MIT remains committed to meeting the need of each enrolling student; a needier population calls for more funds for grants and scholarships.

The Need for Financial Aid

The aggregate undergraduate need for assistance grew again, by \$2,694,000. We assisted only 23 more needy students than last year, but the average need for help rose by almost \$1,000 to \$13,311. In the aggregate, the financial aid program required \$16,000,000 from needy students' family resources, and provided \$31,800,000 in aid dollars. Thus the aid program accounted for two thirds of needy students' total costs.

Scholarships and Grants

The increasingly needy student body produced a turnaround in grants from federal programs, bringing them up by 8 percent; but the overall increase in the need for scholarships this year brought the federal participation percentage figure down to 13.4 percent -- the lowest since the early 1960's. The largest increase was in the Pell Grants brought in by the neediest students, and ROTC scholarships to needy students also increased. Another substantial increase was recorded in income from endowed scholarship funds, the combined result of additional gifts related to the Campaign for MIT, a good investment performance by the portfolio, and especially assiduous attention by the Aid Office to using every available dollar in the inventory of funds. Scholarship awards made directly to needy students by outside sponsors rose again, nearly attaining the \$2 million mark. Overall, the level of awards from designated grant and scholarship resources reached to just below \$12 million; and was 10 percent higher than last year. But these resources once again fell far short of the need, and the program was augmented by \$8,549,000 from unrestricted income, a figure that represents about 14.8 percent of undergraduate tuition income. The New MIT Opportunity Grants Program accounted for just over \$250,000 of this need.

The following table displays the sources of grants and scholarships received by needy students in the last three years:

Scholarships and Grants*

(awarded to undergraduates with need)

<u>Source</u>	<u>1986-87</u>	<u>1987-88</u>	<u>1988-89</u>
Pell Grants	\$ 630,000	\$ 665,000	\$ 837,000
SEO Grants	1,304,000	1,317,000	1,235,000
ROTC Scholarships	767,000	565,000	670,000
Scholarship Endowment	4,813,000	5,379,000	6,410,000
Current Gifts	763,000	1,036,000	821,000
Direct Grants	1,811,000	1,918,000	1,971,000
Unrestricted Funds [¶]	6,121,000	6,969,000	8,549,000
Total Grants Awarded	\$16,209,000	\$17,849,000	\$20,493,000

* 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 Special Program Grants.

Loans

MIT undergraduate students continue to enjoy unlimited access to the loan assistance they need--but they borrowed less than last year. The Perkins Loan Fund (formerly NDS Loans) saw the resumption of a rapid increase in use, reflective of a healthy repayment stream that replenished the fund. We were again able to award up to \$2,000 to each eligible student. Nearly every student with need took a Stafford Student Loan (formerly Guaranteed Student Loan) as well, although the total borrowed under this program by undergraduates fell off markedly from last year. The Technology Loan Fund continues to be the only loan resource for foreign students, and a vital last resort for many US citizens for whom the federal programs are insufficient or unavailable. Undergraduates borrowed 24 percent more from this source than last year, for a total of \$912,000.

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For the second year, the use of loan programs available for students' parents was becalmed, presumably the corollary to increased use of home-equity loans to pay college bills.

The following table details loan use by undergraduate and graduate students:

Loans

(received by needy and non-needy students)

<u>Source</u>	<u>1986-87</u>	<u>1987-88</u>	<u>1988-89</u>
A. <u>Awarded to Undergraduates</u>			
Technology Loan Fund	\$ 766,000	\$ 735,000	\$ 912,000
Perkins/National Direct Loans	2,844,000	2,478,000	3,633,000
Stafford Student Loans	4,834,000	5,068,000	3,495,000
Sub-Total	\$8,444,000	\$8,281,000	8,040,000
B. <u>Awarded to Graduate Students</u>			
Technology Loan Fund	\$1,198,000	\$1,311,000	\$2,066,000
Stafford Student Loans by Commercial Lenders	3,350,000	3,473,000	3,721,000
Stafford Student Loans by MIT	56,000	594,000	691,000
Sub-Total	\$4,604,000	\$5,378,000	\$8,478,000

Work Programs

The job market remained strong in the past year, and the average starting rate for off-campus jobs was again well above the Federal minimum wage. The on-campus minimum wage increased to \$6.25. The number of students working on campus again showed no change.

The College Work-Study Program allocation again increased slightly above the 1987-1988 level and was used entirely to subsidize the on-campus student employment program. Approximately two-thirds of the total 1988-1989 allocation was used to subsidize undergraduate work, and one-third to subsidize graduate student teaching assistantships.

Programs of Interest

•During the year, the new MIT Opportunity Award Program was in effect for 128 of the lowest-income freshmen; and was again a part of the award package of the 131 lowest-income members of the class that will enter in September, 1989. These students are enjoying a significant reduction in the standard "self-help" (loan and job) expectation. The additional relief, seen in the form of additional scholarship aid, will be renewed annually for the expected four years of undergraduate matriculation. The desired outcomes of this initiative are increased application, enrollment, and graduation rates for low-income students.

•Even as the electronic Pell Grant Process (described in last year's report) reached fully-operational status, the SFAO was rapidly bringing into use two other enhancements to its operations. The process of reviewing Stafford Loans in the state of Massachusetts has seen quantum improvement from the addition of an electronic data-base linkage with the state guarantee agency; and the SFAO made extensive modifications to a proprietary need analysis software program, that will allow the aid officer much more time to evaluate the fairness and the effect of the decisions they make. The new process also allows remote transmission of the aid officers' work to the database via modem.

Staff Notes

During the year Associate Director Fred Massie retired from the Institute. Having arrived at MIT from a well-established financial aid career at Brown University, Mr. Massie had served the SFAO well for 10 1/2 years. In that time he successively had responsibility for the office's donor relations activity and for managing the renewal-awards program. During his tenure, Mr. Massie was the principal author of most of the office's brochures, publications, and position papers, bringing to these vehicles a well-developed combination of literary skill and design sense. Under his care the SFAO's public image passed from "obviously-drab" to "unusually-interesting."

To fill the position vacated by Mr. Massie, Ms. Patricia A. Carroll was promoted in May from the support staff to Assistant Director. Assistant Director Lisa A. Oteri, who completed her leave of absence from the office, terminated her staff appointment in May. Steven T. Nalesnik was promoted from Assistant to the Director to Analyst Programmer II.

LEONARD V. GALLAGHER, Director

ACADEMIC STAFF COUNT

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	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	8	-	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17	1	-
SCHOOL of ARCHITECTURE AND PLANNING																				
Architecture	10	2	-	-	6	7	1	-	14	-	-	1	-	-	24	55	3	123	4	6
Urban Studies and Planning	13	1	-	2	3	3	2	-	5	-	-	-	-	-	41	7	-	83	4	21
Media Arts and Sciences Sect.	5	-	-	1	2	5	-	-	-	-	-	2	-	-	54	-	-	69	3	2
Total	28	3	-	3	14	15	4	2	19	-	-	3	-	-	119	62	3	275	11	29
SCHOOL OF ENGINEERING																				
Aeronautics and Astronautics	17	4	-	2	7	9	5	4	8	-	-	3	-	1	134	10	-	204	3	8
Chemical Engineering	20	2	-	-	3	5	1	1	1	-	1	1	1	10	138	27	1	212	-	28
Civil Engineering	21	4	-	-	9	5	-	2	2	-	-	-	-	8	124	22	3	200	5	13
Electrical Engineering and Computer Science	52	15	-	5	30	15	8	-	6	2	-	4	-	1	363	105	2	608	4	8
Materials Science and Engineering	16	5	-	2	8	5	3	1	-	-	-	2	2	12	130	17	-	203	4	27
Mechanical Engineering	28	1	-	1	18	13	5	8	28	-	-	6	1	8	222	32	1	373	4	22
Nuclear Engineering	14	2	-	-	4	1	-	-	1	2	-	-	-	1	79	17	-	121	-	9
Ocean Engineering	12	1	-	-	9	1	1	2	8	-	-	-	-	7	50	7	-	98	-	1
Total	181	34	-	10	91	54	24	18	55	5	1	16	4	48	1,240	237	7	2,025	20	116
SCHOOL OF HUMANITIES AND SOCIAL SCIENCE																				
Economics	19	2	-	-	2	6	-	-	-	-	-	1	-	-	6	25	-	60	3	15
Humanities	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anthropology/Archaeology	3	-	-	-	2	-	-	-	1	-	-	-	-	-	-	-	-	6	1	2
Foreign Languages and Literatures	3	-	-	-	6	2	-	-	22	-	-	-	-	-	-	-	-	33	3	2
History	4	2	-	-	5	2	-	-	-	-	1	-	-	-	-	-	-	14	3	-
Literature	7	2	-	-	5	1	-	-	11	-	-	-	-	-	-	-	-	26	-	-
Music and Theater Arts	5	1	-	-	2	1	-	3	11	-	-	4	-	-	-	-	-	27	1	12
Writing Program	2	1	-	1	2	3	-	1	16	-	-	9	-	-	-	-	-	35	-	6
Linguistics and Philosophy	12	2	-	-	4	3	-	-	-	-	-	-	-	-	16	11	-	48	2	17
Political Science	13	2	-	-	3	6	-	-	3	-	-	-	-	-	42	13	1	83	1	4
Program in Science, Technology, and Society	5	1	-	-	1	1	-	-	-	-	-	-	1	-	1	-	-	10	2	29
Total	73	13	-	1	32	25	-	4	66	-	1	14	1	-	65	49	1	345	18	88
SLOAN SCHOOL OF MANAGEMENT																				
Management	32	3	-	2	18	30	1	7	6	-	-	-	1	-	54	67	-	221	10	19
SCHOOL OF SCIENCE																				
Program in Applied Biological Sciences	1	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	3	-	-
Biology	33	3	-	-	7	12	1	1	-	-	-	1	-	6	36	-	-	43	-	4
Chemistry	22	2	-	-	3	4	3	1	-	1	-	1	-	55	143	52	-	287	-	86
Earth, Atmospheric, and Planetary Sciences	21	2	-	-	8	6	1	1	-	2	1	-	-	11	94	16	-	163	8	25
Mathematics	35	1	-	-	7	11	-	1	2	-	19	-	-	3	31	46	-	156	5	28
Physics	60	4	-	-	4	17	3	-	1	13	-	8	-	11	221	41	-	383	4	17
Total	172	12	-	1	29	50	8	4	4	16	24	10	-	136	556	155	-	1,177	17	251

MITAKER COLLEGE of Health Sciences and Technology	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	2	-	3	
Brain and Cognitive Sciences	16	2	-	-	6	5	-	2	-	-	2	-	7	6	7	-	53	-	45	
Toxicology	1	2	-	-	1	1	-	-	1	-	-	-	10	-	-	-	16	-	11	
Total	17	4	-	-	7	7	-	1	3	-	-	2	-	17	6	7	-	71	-	59
Administration	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	
Force Aerospace Studies	-	-	-	-	-	-	-	-	-	-	8	-	-	-	-	-	8	1	-	
Official Intelligence Laboratory	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	4	
Olethic Department	-	1	-	-	10	5	-	-	1	-	12	-	-	-	-	-	29	-	23	
Technology Process Engineering Ctr.	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	3	-	10	
Center for Advanced Engineering Studies	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	
Center for Advanced Visual Studies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	
Center for Cancer Research	-	-	-	-	-	-	-	-	-	-	-	-	20	-	-	-	20	-	64	
Center for Cognitive Science	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	23	
Center for Environmental Health Sciences	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	-	3	-	3	
Center for International Studies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20	
Center for Technology, Policy, and Industrial Development	-	-	-	-	-	-	-	-	-	-	-	1	-	5	1	-	7	-	6	
Center for Materials Research in Archaeology and Ethnology	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	2	-	5	
Center for Materials Science and Engineering	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	2	
Center for Space Research	-	-	-	-	-	-	-	-	1	-	-	-	4	-	-	-	5	-	8	
Center for Transportation Studies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Chemical Research Center	-	-	-	-	-	-	-	-	-	-	-	-	6	1	-	-	7	-	20	
Division of Comparative Medicine	-	1	-	-	-	-	-	-	-	-	-	-	6	-	-	-	7	-	10	
Energy Laboratory	-	-	-	-	-	-	-	-	-	-	-	-	2	1	-	-	3	-	13	
Experimental Study Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Francis Bitter National Magnet Laboratory	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	46	
Harvard-MIT Division of Health Sciences and Technology	3	-	-	-	1	2	-	1	3	1	-	1	3	43	2	-	60	2	23	
Haystack Observatory	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	1	
Laboratory of Architecture and Planning	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	7	
Laboratory for Computer Science	-	-	-	-	-	-	-	-	2	-	-	-	6	-	-	-	8	-	16	
Laboratory for Electromagnetic and Electronic Systems	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	
Laboratory for Information and Decision Systems	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	2	-	4	
Laboratory for Manufacturing and Productivity	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	
Laboratory for Nuclear Science	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	19	
Materials Processing Center	-	-	-	-	-	-	-	-	1	-	-	-	6	-	-	-	7	-	12	
Media Laboratory	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18	
Medical Department	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	156	
Library Science	-	-	-	-	-	-	-	-	-	1	7	-	-	-	-	-	8	1	-	
Nuclear Science	-	-	-	-	-	-	-	-	-	-	8	-	-	-	-	-	8	3	-	
Nuclear Reactor Laboratory	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-	13	
Office of the Dean for Student Affairs	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	
Office of the Provost	1	1	-	-	1	-	-	-	-	-	-	-	2	-	-	-	5	-	10	
Operations Research Center	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Plasma Fusion Center	-	-	-	-	-	-	-	-	3	-	-	-	1	-	-	-	4	-	13	
Project Athena	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14	
Research Laboratory of Electronics	-	-	-	-	-	-	-	-	-	-	-	-	6	1	-	-	7	-	50	
Grant Program	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Spectroscopy Laboratory	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	2	-	20	
Statistics Center	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-	2	-	-	
Student Activities	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	5	-	1	
Total	4	4	-	-	12	7	-	1	5	13	13	30	2	73	53	4	-	221	7	659
Grand Total	515²	73²	9²	17²	203²	188²	37²	37²	158²	34	39²	75²	8	274	2,093	581²	11²	4,352	84^{3,4}	1,221³

Faculty Ex Officiis* 27

4,379

Total Faculty 1,069
 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.
 Total Teaching Staff 1,943
 not included in preceding total
 Visiting Professors include 40 Professors, 22 Associate Professors, 21 Assistant Professors, 1 Institute Professor.

CLASSIFICATION OF STUDENTS BY SCHOOL, COURSE, AND YEAR, 1988-89*

568 Vice President for Financial Operations

COURSE NAME	Undergraduates			Graduates	Grad. Non-Res. ¹	Total	Course Number
	2	3	4				
SCHOOL OF ARCHITECTURE AND PLANNING							
Architecture, IV	37	35	34	253 (4)	10	369 (4)	IV
Architecture, IV-B	7	2	6	-	-	15	IV-B
Urban Studies and Planning, XI	-	3	-	175 (17)	28	206 (17)	XI
Total	44	40	40	428 (21)	38	590 (21)	Total
SCHOOL OF ENGINEERING							
Aeronautics and Astronautics, XVI	106	79	118	210 (12)	-	513 (12)	XVI
Aeronautics and Astronautics, XVI-B (Cooperative)	-	1	1	-	-	2	XVI-B
Aeronautics and Astronautics, XVI-C (Internship)	-	16	11	-	-	27	XVI-C
Chemical Engineering, X	40	37	43	237 (4)	1	358 (4)	X
Chemical Engineering, X-C	6	1	1	-	-	8	X-C
Civil Engineering, I	23	21	14	250 (10)	4	312 (10)	I
Civil Engineering, I-A	10	8	10	-	-	28	I-A
Civil Engineering, I-W (Woods Hole)	-	-	-	4	-	4	I-W
Electrical Engineering and Computer Science, VI	-	-	-	646 (80)	2	648 (80)	VI
Program 1-Electrical Science and Engineering	145	117 (1)	157 (1)	-	-	419 (2)	VI-1
Program 3-Computer Science and Engineering	99	66	89	-	-	254	VI-3
Electrical Engineering and Computer Science, VI-A (Cooperative)	-	-	-	115 (1)	-	115 (1)	VI-A (Co-op)
Program 1-Electrical Science and Engineering	-	58	66	-	-	124	VI-1 (Co-op)
Program 3-Computer Science and Engineering	-	25	28	-	-	53	VI-3 (Co-op)
Electrical Engineering and Computer Science, VI-W (Woods Hole)	-	-	-	2	-	2	VI-W
Materials Science and Engineering, III	30	11	10	204 (9)	3	258 (9)	III
Materials Science and Engineering, III-A	2	2	2	-	-	6	III-A
Materials Science and Engineering, III-B (Internship)	8	25	39	-	-	72	III-B
Mechanical Engineering, II	140	107	137	417 (35)	2	803 (35)	II
Mechanical Engineering, II-A	8	10	20	-	-	38	II-A
Mechanical Engineering, II-B (Internship)	-	33	20	-	-	53	II-B
Mechanical Engineering, II-W (Woods Hole)	-	-	-	3	-	3	II-W
Nuclear Engineering, XXII	7	8	6	150 (1)	2	173 (1)	XXII
Nuclear Engineering, XXII-A (Internship)	-	3	4	-	-	7	XXII-A
Ocean Engineering, XIII	-	5	3	67 (4)	1	76 (4)	XIII
Ocean Engineering, XIII-W (Woods Hole)	-	-	-	20	-	20	XIII-W
Naval Construction and Engineering, XIII-A	-	-	-	51	-	51	XIII-A
Ocean Systems Management, XIII-B	-	-	-	14	-	14	XIII-B
Center for Advanced Engineering Study, EN	-	-	-	57 (57)	-	57 (57)	EN
Total	624	633 (1)	779 (1)	2,447 (213)	15	4,498 (215)	Total
SCHOOL OF HUMANITIES AND SOCIAL SCIENCE							
Economics, XIV	29	35	25	127 (7)	15	231 (7)	XIV
Humanities, XXI	3	6	11	-	-	20	XXI
Humanities and Engineering, XXI-E	1	-	3	-	-	4	XXI-E
Humanities and Science, XXI-S	4	6	9	-	-	19	XXI-S
Linguistics and Philosophy, XXIV	2	3	5	61 (1)	10	81 (1)	XXIV
Political Science, XVII	6	14	15	129 (4)	31	195 (4)	XVII
Program in Science, Technology, and Society, STS	-	-	-	4	-	4	STS
Total	45	64	68	321 (12)	56	554 (12)	Total

SCHOOL OF MANAGEMENT							
Management, XV	31 (1)	37	47	426 (21)	7	548 (22)	XV
Management Fellows, XV-A	-	-	-	63 (9)	-	63 (9)	XV-A
Management-Operations Research, XV-B	-	-	-	16	-	16	XV-B
Management-Ph.D., XV-P	-	-	-	86	-	86	XV-P
Total	31 (1)	37	47	591 (30)	7	713 (31)	Total
SCHOOL OF SCIENCE							
Program in Applied Biological Sciences, XX	-	-	-	64	-	64	XX
Biology, VII	86	59	63	176 (3)	-	384 (3)	VII
Biology, VII-A	5	7	13	-	-	25	VII-A
Biology, VII-B	-	5	12	-	-	17	VII-B
Biology, VII-W (Woods Hole)	-	-	-	18	-	18	VII-W
Chemistry, V	20	31	23	229 (1)	6	309 (1)	V
Earth, Atmospheric, and Planetary Sciences, XII	6	11	11	107	6	141	XII
Earth, Atmospheric, and Planetary Sciences, XII-W (Woods Hole)	-	-	-	64	-	64	XII-W
Mathematics, XVIII	42	30	40	128 (5)	12	252 (5)	XVIII
Mathematics with Computer Science, XVIII-C	10	18	20	-	-	48	XVIII-C
Physics, VIII	62	52	67	309 (4)	-	490 (4)	VIII
Physics, VIII-A	24	17	21	-	-	62	VIII-A
Total	255	230	270	1,095 (13)	24	1,874 (13)	Total
HITAKER COLLEGE of Health Sciences and Technology							
Brain and Cognitive Sciences, IX	10	12	20	56 (2)	-	98 (2)	IX
Health Policy and Management, HPM	-	-	-	6	-	6	HPM
Total	10	12	20	62	0	104	Total
Harvard-MIT Division of Health Sciences and Technology, HST							
Undesignated	52	27 (27)	-	-	-	79 (27)	Undesignated
First Year	997	-	-	-	-	997	First Year
Grand Total	997	1,061 (1)	1,043 (28)	1,224 (1)	140	9,500 (383)	Total
Non-Institute Harvard	24	9	32	231	-	325	
Non-Institute Tufts	11	14	3	7	-	35	
Non-Institute Wellesley	7	47	41	14	-	109	

All figures include special students (special students also shown separately in parentheses)
 Non-Resident Graduate Students

Not included in above totals:

1 student in the second year, 8 students in the third year, 5 students in the fourth year on Foreign Study
 1 student in the second year, 1 student in the fourth year on Domestic Study

WOMEN STUDENTS BY SCHOOL, COURSE, AND YEAR, 1988-89¹

570 Vice President for Financial Operations

COURSE NAME	Undergraduate			Graduate	Grad. Non- Res.	Total
	2	3	4			
SCHOOL OF ARCHITECTURE AND PLANNING						
Architecture, IV	25	19	18	67 (2)	2	131 (2)
Architecture, IV-B	2	1	2	-	-	5
Urban Studies and Planning, XI	-	1	-	75 (2)	13	89 (2)
Total	27	21	20	142 (4)	15	225 (4)
SCHOOL OF ENGINEERING						
Aeronautics and Astronautics, XVI	22	20	20	20	-	82
Aeronautics and Astronautics, XVI-C (Internship)	-	5	1	-	-	6
Chemical Engineering, X	20	25	21	41 (1)	-	107 (1)
Chemical Engineering, X-C	6	1	-	-	-	7
Civil Engineering, I	8	7	1	47 (1)	-	63 (1)
Civil Engineering, I-A	4	2	3	-	-	9
Electrical Engineering and Computer Science, VI	-	-	-	100 (8)	-	100 (8)
Program 1-Electrical Science and Engineering	33	33	28	-	-	94
Program 3-Computer Science and Engineering	23	11	13	-	-	47
Electrical Engineering and Computer Science, VI-A (Cooperative)	-	-	-	16	-	16
Program 1-Electrical Science and Engineering	-	19	13	-	-	32
Program 3-Computer Science and Engineering	-	8	2	-	-	10
Materials Science and Engineering, III	17	5	4	53 (3)	1	80 (3)
Materials Science and Engineering, III-A	1	-	2	-	-	3
Materials Science and Engineering, III-B (Internship)	6	16	17	-	-	39
Mechanical Engineering, II	35	36	28	63 (7)	-	162 (7)
Mechanical Engineering, II-A	4	3	10	-	-	17
Mechanical Engineering, II-B (Internship)	-	8	8	-	-	16
Nuclear Engineering, XXII	4	2	-	13	1	20
Nuclear Engineering, XXII-A (Internship)	-	1	3	-	-	4
Ocean Engineering, XIII	-	1	1	4	1	7
Naval Construction and Engineering, XIII-A	-	-	-	1	-	1
Ocean Systems Management, XIII-B	-	-	-	1	-	1
Center for Advanced Engineering Study, EN	-	-	-	7 (7)	-	7 (7)
Total	183	203	175	366 (27)	3	930 (27)
SCHOOL OF HUMANITIES AND SOCIAL SCIENCE						
Economics, XIV	5	16	6	24 (4)	1	52 (4)
Humanities, XXI	2	2	4	-	-	8
Humanities and Engineering, XXI-E	1	-	-	-	-	1
Humanities and Science, XXI-S	2	5	5	-	-	12
Linguistics and Philosophy, XXIV	1	2	3	21 (1)	4	31 (1)
Political Science, XVII	3	6	-	42 (3)	13	64 (3)
Program in Science, Technology, and Society, STS	-	-	-	2	-	2
Total	14	31	18	89 (8)	18	170 (8)

LOAN SCHOOL OF MANAGEMENT							
Management, XV	17 (1)	14	12	73 (6)	1	117 (7)	
Management Fellows, XV-A	-	-	-	3 (1)	-	3 (1)	
Management-Operations Research, XV-B	-	-	-	4	-	4	
Management-Ph.D., XV-P	-	-	-	14	-	14	
total	17 (1)	14	12	94 (7)	1	138 (8)	
SCHOOL OF SCIENCE							
Program in Applied Biological Sciences, XX	-	-	-	32	-	32	
Biology, VII	55	36	29	67 (1)	-	187 (1)	
Biology, VII-A	2	2	1	-	-	5	
Biology, VII-B	-	3	7	-	-	10	
Biology, VII-W (Woods Hole)	-	-	-	9	-	9	
Chemistry, V	10	19	10	59	3	101	
Earth, Atmospheric, and Planetary Sciences, XII	4	7	4	20	3	38	
Earth, Atmospheric, and Planetary Sciences, XII-W (Woods Hole)	-	-	-	20	-	20	
Mathematics, XVIII	16	18	9	15	3	61	
Mathematics with Computer Science, XVIII-C	2	2	5	-	-	9	
Physics, VIII	8	14	13	28	-	63	
Physics, VIII-A	5	3	5	-	-	13	
total	102	104	83	250 (1)	9	548 (1)	
HITAKER COLLEGE of Health Sciences and Technology							
Brain and Cognitive Sciences, IX	3	7	5	15	-	30	
Health Policy and Management, HPM	-	-	-	1	-	1	
Harvard-MIT Division of Health Sciences and Technology, HST							
	-	-	-	14 (7)	-	14 (7)	
Undesignated	25	10 (10)	-	-	-	35 (10)	
First Year	338	-	-	-	-	338	
Grand Total	338	371 (1)	390 (10)	313	971 (54)	46	2,429 (65)

Also included in Classification of Students

11 figures include special students (special students also shown separately in parentheses).

Not included in above totals:

3 students in the third year, 3 students in the fourth year on Foreign Study.

NUMBER OF DEGREES AWARDED IN SEPTEMBER 1988, FEBRUARY 1989, AND JUNE 1989

572 Vice President for Financial Operations

	S.B.			S.M.			M.ARCH. M.C.P.			ENGINEER			PH.D.			SC.D.			TOTAL		
	S E P T	F E B	J U N E	S E P T	F E B	J U N E	S E P T	F E B	J U N E	S E P T	F E B	J U N E	S E P T	F E B	J U N E	S E P T	F E B	J U N E	S E P T	F E B	J U N E
SCHOOL OF ARCHITECTURE AND PLANNING																					
Architecture	-	-	-	-	-	-	-	18	14	-	-	-	-	1	2	-	-	-	-	19	16
Undesignated	-	1	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	3
Architecture Studies	-	-	-	3	4	23	-	-	-	-	-	-	-	-	-	-	-	-	3	4	23
Art and Design	-	4	29	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	29
Planning	-	-	-	-	-	-	3	5	37	-	-	-	-	-	-	-	-	-	3	5	37
Real Estate Development	-	-	-	35	-	2	-	-	-	-	-	-	-	-	-	-	-	-	35	-	2
Urban Studies and Planning	-	-	-	-	-	-	-	-	-	-	-	-	-	1	4	-	-	-	-	1	4
Visual Studies	-	-	-	1	6	8	-	-	-	-	-	-	-	-	-	-	-	-	1	6	8
total	-	5	32	39	10	33	3	23	51	-	-	-	-	2	6	-	-	-	42	40	122
SCHOOL OF ENGINEERING																					
Aeronautics and Astronautics	1	8	103	10	15	25	-	-	-	-	-	-	1	6	5	1	-	1	13	29	134
Ceramics	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Chemical Engineering	1	4	40	1	-	-	-	-	-	-	-	-	2	10	13	2	1	1	6	15	54
Undesignated	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Chemical Engineering Practice	-	-	7	6	10	17	-	-	-	-	-	-	-	-	-	-	-	-	6	10	17
Civil Engineering	-	1	10	15	12	23	-	-	-	1	1	-	1	8	8	1	3	1	18	25	42
Undesignated	-	1	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	11
Computer Science and Engineering	9	13	94	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	13	94
Electrical Engineering	12	18	188	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	18	188
Electrical Engineering and Computer Science	-	-	-	33	44	106	-	-	-	4	3	9	14	20	21	2	2	-	53	69	136
Electronic Materials	-	-	-	3	1	6	-	-	-	-	-	-	-	-	-	-	-	-	3	1	6
Materials Engineering	-	-	-	-	3	5	-	-	-	-	-	-	-	-	-	-	-	-	-	3	5
Materials Science	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Materials Science and Engineering	1	5	36	-	-	-	-	-	-	-	-	-	8	8	11	2	2	3	11	15	50
Undesignated	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Mechanical Engineering	5	10	136	23	19	54	-	-	-	1	-	-	6	10	19	3	3	6	37	43	215
Undesignated	1	-	19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	19
Metallurgy	-	-	-	3	3	2	-	-	-	-	-	-	-	-	-	-	-	-	3	3	2
Naval Architecture and Marine Engineering	-	1	-	3	3	8	-	-	-	-	-	-	-	-	-	-	-	-	3	4	8
Naval Engineering	-	-	-	-	-	-	-	-	-	-	14	-	-	-	-	-	-	-	-	-	14
Nuclear Engineering	-	-	6	3	10	12	-	-	-	1	2	-	6	2	5	-	-	-	9	13	25
Ocean Engineering	-	-	3	3	-	2	-	-	-	1	2	-	-	4	2	-	-	-	4	4	9
Ocean Systems Management	-	-	-	-	1	3	-	-	-	-	-	-	-	1	2	-	-	-	-	2	5
Polymers	-	-	-	1	1	2	-	-	-	-	-	-	-	-	-	-	-	-	1	1	2
total	30	61	649	104	124	266	-	-	-	6	6	27	38	69	86	11	11	12	189	271	1,040
SCHOOL OF HUMANITIES AND SOCIAL SCIENCE																					
Economics	4	1	20	1	1	-	-	-	-	-	-	-	4	12	11	-	-	-	9	14	31
Humanities	1	1	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	17
Humanities and Engineering	-	3	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	6
Humanities and Science	1	2	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	5
Linguistics	-	-	-	-	-	-	-	-	-	-	-	-	3	3	-	-	-	-	3	3	-
Philosophy	-	-	5	-	1	1	-	-	-	-	-	-	1	-	1	-	-	-	1	1	7
Political Science	-	1	12	2	7	10	-	-	-	-	-	-	1	4	7	-	-	-	3	12	29
Political Science and Public Policy	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
total	6	8	65	3	10	11	-	-	-	-	-	-	9	19	19	-	-	-	18	37	95

DAN SCHOOL OF MANAGEMENT																					
Management	-	-	-	4	17	225	-	-	-	-	2	3	4	-	-	-	6	20	229		
Management Science	1	4	40	-	-	-	-	-	-	-	-	-	-	-	-	-	1	4	40		
total	1	4	40	4	17	225	-	-	-	-	2	3	4	-	-	-	7	24	269		
SCHOOL OF SCIENCE																					
Applied Biological Sciences	-	-	-	2	-	1	-	-	-	-	6	4	2	-	-	-	8	4	3		
Biochemical Engineering	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1		
Biology	-	-	-	1	1	2	-	-	-	-	6	7	11	-	-	-	7	8	13		
Undesignated	-	6	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	17		
Chemistry	1	-	25	1	-	-	-	-	-	16	9	10	-	-	1	-	18	9	36		
Earth and Planetary Sciences	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Earth, Atmospheric, and Planetary Sciences	-	4	7	-	-	-	-	-	-	4	8	4	-	1	-	-	4	13	11		
Life Sciences	-	6	62	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	62		
Mathematics	-	5	42	-	2	-	-	-	-	8	1	25	-	-	-	-	8	8	67		
Mathematics with Computer Science	-	-	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15		
Meteorology	-	-	-	1	2	-	-	-	-	-	-	-	-	-	-	-	1	2	-		
Physics	7	5	75	-	2	5	-	-	-	12	15	12	-	-	-	-	19	22	92		
total	8	26	243	5	7	9	-	-	-	52	44	64	-	1	1	-	65	78	317		
MITAKER COLLEGE of Health Sciences and Technology																					
Cognitive Science	-	4	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	11		
Brain and Cognitive Sciences	-	-	-	-	1	2	-	-	-	2	3	3	-	-	-	-	2	4	5		
Toxicology	-	-	-	-	-	1	-	-	-	-	-	2	-	-	-	-	-	-	3		
total	-	4	11	-	1	3	-	-	-	2	3	5	-	-	-	-	2	8	19		
Harvard-MIT Division of Health Sciences and Technology																					
Medical Engineering	-	-	-	-	-	1	-	-	-	3	1	4	-	-	-	-	3	1	4		
Management of Technology																					
Innovations Research	-	-	-	-	-	29	-	-	-	-	-	-	-	-	-	-	-	-	29		
Technology and Policy	-	-	-	1	5	8	-	-	-	-	-	-	-	-	-	-	1	5	8		
Transportation	-	-	-	5	4	13	-	-	-	-	-	-	-	-	-	-	5	4	13		
Thout Course Specification	-	-	-	1	3	3	-	-	-	-	-	-	-	-	-	-	1	3	3		
	-	-	-	17	9	14	-	-	-	-	-	-	-	-	-	-	17	9	14		
Shared Jointly with Woods Hole Oceanographic Institution																					
Biology	-	-	-	1	-	-	-	-	-	-	2	1	-	-	-	-	1	2	1		
Oil Engineering	-	-	-	-	-	-	-	-	-	1	-	2	-	-	-	-	1	-	2		
Earth, Atmospheric, and Planetary Sciences	-	-	-	3	-	-	-	-	-	3	2	7	-	-	-	-	6	2	7		
Chemical Engineering	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-		
Ocean Engineering	-	-	-	2	-	-	-	-	2	-	-	1	-	-	-	-	5	-	1		
Thout Course Specification	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-		
Grand Total	45	108	1,040	186	190	615	3	23	51	8	6	27	111	146	199	11	12	13	364	485	1,945

Office of Sponsored Programs

For fiscal year 1989, the total volume of sponsored research performed on campus approximated \$285,728,000. This represents an increase of 6.1% over fiscal 1988 volume of \$269,394,000 which was, in turn, an increase of only 2.75% over the prior year.

Federal agency sponsorship increased by 2.4%, with Department of Defense funding up 2.3%, the Department of Health and Human Services up 7.1%, and the National Aeronautics and Space Administration up 22.0%. Department of Energy funding decreased by 2.85%, and the National Science Foundation by .5%.

Of the non-Federal sponsors, industrial funding increased by 18.8%, compared with a decrease of 4% in 1988. Support from private foundations and other non-profit sponsors increased by 19.3%. It should be noted, however, that sponsorship characterized as non-Federal may include subcontracts which pass to MIT Federal funds awarded to the sponsor by the government.

The breakdown by sponsor is shown in the following table:

CAMPUS RESEARCH VOLUME BY SPONSOR -1983-1989

(in thousands of dollars)

<u>FEDERAL</u>		<u>1983</u>	<u>1984</u>	<u>1985</u>	<u>1986</u>	<u>1987</u>	<u>1988</u>	<u>1989</u>
DOE	\$	48,271	51,489	56,363	54,511	55,062	55,629	54,045
DHHS	\$	30,870	36,324	40,252	45,735	47,310	49,070	52,565
DOD	\$	31,883	34,626	38,578	43,418	45,418	46,836	47,921
NSF	\$	31,003	30,876	33,658	36,772	38,091	39,177	38,962
NASA	\$	10,445	11,888	12,315	12,864	12,706	12,509	15,256
Other	\$	10,400	9,783	8,863	7,823	8,238	7,283	6,713
Federal Subtotal	\$	<u>162,872</u>	<u>174,986</u>	<u>190,029</u>	<u>201,123</u>	<u>206,825</u>	<u>210,504</u>	<u>215,462</u>
<u>NON-FEDERAL</u>								
Industry	\$	19,753	27,686	33,456	36,290	36,601	35,315	41,937
Nonprofit	\$	13,196	15,743	15,282	15,532	15,319	19,779	23,602
Other	\$	3,452	3,166	2,958	3,151	4,009	3,796	4,727
Non-Federal Subtotal	\$	<u>36,401</u>	<u>46,595</u>	<u>51,696</u>	<u>54,973</u>	<u>55,929</u>	<u>58,890</u>	<u>70,266</u>
<u>TOTAL</u>	\$	<u>199,273</u>	<u>221,581</u>	<u>241,725</u>	<u>256,096</u>	<u>262,754</u>	<u>269,394</u>	<u>285,728</u>

SIGNIFICANT DEVELOPMENTS

As in past years, a variety of external developments had an impact on sponsored research programs. Among these are the following:

Ethics in Science

During the year, Congress and the Federal agencies devoted unusual attention to various aspects of ethics in science.

A well publicized Congressional hearing into allegations of misconduct resulted in a debate over the definition of misconduct as opposed to error, the ability of research institutions to police themselves in the absence of Federal regulation, and the proper role of Congress in investigating scientific matters.

The Public Health Service issued final regulations concerning the handling of alleged misconduct in connection with PHS funded research grants. The regulations deal with the reporting of alleged misconduct, conducting of inquiries and investigations, etc.

NIH issued a notice of its intent to develop conflict of interest regulations as a result of "growing public concern...that NIH act to limit possibilities for actual or apparent financial conflicts of interest by investigators in research and development projects funded by NIH awards."

Procurement Integrity

Last year an unusually large number of statutes and regulations were implemented to ensure integrity in the procurement process. Although intended for defense contractors, they apply equally to universities conducting research under contracts. Among them are DOD regulations on "Fraud, Waste and Abuse," which involve telephone hot lines and systems to detect fraud; restrictions on the hiring of ex-DOD employees; government wide suspension and debarment rules; and a proliferation of certification requirements in connection with anti-kickbacks, cost and pricing data, loan delinquency status, etc.

Last spring, DOD issued regulations to implement a statutory requirement that "DOD may not award a contract to a college or university for the performance of research or development or for the construction of a facility unless the contract is awarded using competitive procedures." This, in effect, repeals certain statutory exemptions which permitted awards to universities without use of the bidding procedures common to industry.

Drug Free Workplace

In January the Office of Management and Budget issued government-wide regulations, to be effective March 18, 1989, implementing the Drug Free Workplace Act, which is directed at the use or possession of drugs at the workplace in connection with the performance of Federal grants and contracts. MIT has since then issued its implementing policy guidance.

Effective October 31, 1988, DOD issued regulations entitled Drug Free Workforce which is directed toward achieving a drug free work force in connection with the performance of DOD contracts by prohibiting the use of drugs on or off duty and mandating, under certain circumstances, employee testing that could lead to sanctions for off duty use of illegal drugs.

Animal Welfare Regulations

Statutory and regulatory activity relating to animal welfare continued last year. In March, for example, a component of the Agriculture Department issued new sections of its Animal Welfare Rules, which propose standards for the handling, care, treatment and transportation of animals, which have been criticized by research and veterinary groups as constituting micromanagement rather than a reasonable standard of performance.

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On the other hand, the City of Cambridge has adopted new animal care regulations which have been generally characterized by Cambridge research groups, including MIT, as achieving a reasonable balance between the interests of researchers and animal welfare advocates.

Legislation introduced last year concerning use of animals for research included the Consumer Products Safe Testing Act, which would prohibit all acute toxicity testing using animals; the Animal Research Facilities Protection Act, which would make it a federal crime to steal, destroy or make unauthorized use of research animals, equipment or data; and the Information Dissemination and Research Accountability Act (introduced for the sixth time) which would form a National Center for Research Accountability in which 20 Presidential appointees would review all research proposals involving animals.

Simplification of Grants Administration

At the same time that new regulations were increasing in many areas, the effort to simplify grants administration continued. OMB last year authorized Federal agencies to adopt some of the liberal features of a demonstration project conducted in Florida, and MIT has been able to simplify administrative requirements involving pre-award costs, no-cost extensions, purchase of equipment, travel, and carry-forward of unexpended funds.

In addition, a number of other developments had a favorable impact on grants administration, such as the increased use of grants by DOE and ONR; simplification of NSF procedures for submitting continuation proposals; elimination of the NSF organizational prior approval system, and liberalization of the NIH prior approval system.

Costs of Research

As in past years, efforts directed at containing the costs of research continued. A report of the Association of American Universities making suggestions for changes in the system of indirect costs was made widely available during the spring. The report stems from a concern that the system of indirect costs, "although intrinsically sound, has been the source of continual frustration for all concerned because it is complex and not easily understood or explained....In the process, too much political capital is expended, perhaps costing universities not only dollars, but credibility as well."

At year end, universities were attempting to remove various restrictions on the full reimbursement of Federally sponsored research. Last year, for example, in response to a statutory requirement, NSF placed a ceiling on the rate of compensation which could be charged to NSF grants. For those paid a rate in excess of the ceiling, the unreimbursed portion of their effort on the grant was made up by the MIT department or laboratory. It was unclear at year end whether that limitation would continue in 1990. Similarly, the appropriations bill for the U.S. Department of Agriculture for 1990 contained language that would limit indirect cost reimbursement to 25% of direct costs, a restriction that might also be mandated for other Federal agencies.

In the spring, the DHHS Office of Inspector General finished auditing eight universities and was preparing to expand the audit to thirty-five more. Audit issues raised to date include the charging of the cost of proposal preparation, the manner in which the costs of service centers such as computing centers, animal facilities, telecommunications, etc. are reallocated to grants and contracts, and the volume of cost transfers between projects.

Competitiveness and foreign countries

The extent to which U.S. universities should disseminate research results and provide technology transfer to foreign countries became the focus of Congressional hearings directed at the various industrial affiliate programs conducted by universities, including the Industrial Liaison Program at MIT.

Personnel Changes

Bonnie Schaefer resigned as a contract administrator November 21 to join her husband in France, and Italo A. Rufo resigned as a contract administrator December 2 to accept a similar position at Brandeis University. Clifford Goodridge was promoted November 1 to Assistant Contract Administrator, Maria Karatzas joined OSP March 21 as an Assistant Contract Administrator, and Paul McQuillan joined OSP March 1 as a Contract Administrator.

GEORGE H. DUMMER

VICE PRESIDENT FOR INFORMATION SYSTEMS

Growth in both the number and power of computers on the MIT campus has continued unabated during the 1989 fiscal year. It has been less than a decade since the first production microcomputer came on the scenes heralding the transition of computing power from the data center to the desktop. Yet, in these few years we have seen the computing power packaged for the desktop grow by almost two orders of magnitude. And, the process will continue at similar rates for the next decade.

As this occurs, the importance of interconnecting our computers, which is well underway, will be better understood and the demand for higher speed, more secure networks will grow. Along with the network growth will come increased need for network based services such as authentication and authorization; large file storage systems; databases containing information such as the library card catalogue, the full text of documents including graphics, information on the classroom subjects offered in a given year, job openings at the Institute, etc.; electronic directories; electronic mail; higher performance computing engines such as supercomputers; etc. Information Systems' charter includes responsibility for enabling this common infrastructure which will permit the more effective use the technology that will be available to us in the very near future.

A number of specific activities during the past year moved Information Systems (IS) in this direction. These activities, as well as other of our work, is detailed in the sections which follow. Highlights include:

- **AT&T 5ESS Digital PBX.** MIT began to provide telephone service to its residential community on August 12, 1988 and to its business community on October 28, 1988 via the 5ESS. Ownership and operational and administrative control occurred on February 10, 1989.
- **MIT Supercomputer.** During the 1989 fiscal year MIT created a Supercomputer Facility and entered into an agreement with Cray Research to lease a Cray 2. This machine is being installed in W91 and will be managed by Operations and Systems under a facilities management agreement.
- **New England Regional Network (NEARnet).** Over the past year MIT joined with Harvard and Boston Universities to form NEARnet to provide high speed computer networking, first between our three institutions, and then to other organizations – colleges and universities, as well as industrial and government research laboratories – throughout the New England area. The core of the network operates at a data rate of 10 million bits per second and is the fastest interorganizational network in the United States. Initial interconnections became active on February 15, 1989 and the network currently provides connectivity to 12 organizations. Growth is strong with another 20 organizations expected to connect to the network in the next six months. Connectivity is also provided to the NSFnet via a connection to the John von Neumann National Supercomputer Facility.
- **Distributed Computing.** Work continued on a number of projects focused on developing our computing infrastructure. These include:

Electronic Mail – A project was initiated to develop a campus-wide electronic mail strategy, and a production-quality electronic mail facility for Macintosh and MS-DOS users. The Stanford MH software was selected as a base for our Macintosh and MS-DOS clients based on its compatibility with MIT's computing environment, the availability of its source code, and the quality of its Macintosh interface. A very successful alpha test of the product was completed late in the year. Following modifications to the software and further testing, this software will be released to the community in Fall 1989. Discussions were also held with Project Athena on a unified name space for MIT and a strategy was agreed upon that will be implemented by Fall 1989.

Network Connectivity – Another distributed computing project focused on the provision of timely network connectivity. Initial recommendations from this work included recommended service offerings, potential costs for the necessary infrastructure work to provide services to prime locations on campus with two week service delivery, as well as potential pricing scenarios. Work continues to develop a phased approach for the infrastructure work and a service plan for an Appletalk/campus network service.

- **Vax Resource Center (VRC)** – The VRC increased its client base during its second year of business, providing discounted DEC maintenance services for 300 DEC CPUs on campus and discounted software licenses and update services for 135 DEC CPUs.
- **Microcomputer Center (MCC)** – Early in fiscal 1989 the MCC moved to its new facility in the Stratton Student Center providing several new services to the community and improvements in the quality of existing services. PC Support is now located within the MCC providing rapid maintenance and repair service. Total sales volume for the MCC has steadily increased in each of its five years of operation.

Although officially at its end, work associated with many of the activities begun under the Strategic Plan for Administrative Information Systems will continue. Of primary importance in this regard are the development of a set of Administrative Computing Principles, the decision to follow a formal methodology in the development and major enhancement or modification of our administrative information systems, and the decision to formally involve the Administrative Computing Steering Committee in decisions concerning administrative computing expenditures.

Information Security efforts continued to be well received throughout the MIT community. Highlights of the year's activities include: A review of the security policy statement by members of the Institute Committee on Privacy; the publication of a monthly Information Security Newsletter; evaluation of hardware security devices for Macintosh, MS-DOS, and other workstations; formation of Continuity Planning and Risk Assessment Committees; the publication of a security awareness brochure; an IAP Seminar on microcomputer security; and meetings with representatives of several MIT departments to provide overviews and develop recovery plans for their information systems.

Personnel

IS' continued commitment to affirmative action led to the revision of our Search Plan to include the requirement that all open IS administrative staff positions be listed with two minority recruiting agencies. Our association with these agencies ended when they required an exclusive contract to fill all open positions. We are working closely with an advertising agency to identify professional minority publications that will attract a larger pool of minority applicants for our staff openings. Also, IS plans to establish a task force during the coming year to develop new ideas to identify and hire underrepresented minorities. This year we did identify and hire a number highly of qualified women.

At year-end, Stephen M. Bayle, Director of Information Services, resigned to form an educational software start-up company.

JAMES D. BRUCE
CECILIA R. d'OLIVEIRA

ADMINISTRATIVE SYSTEMS DEVELOPMENT

In 1989, Administrative Systems Development (ASD) continued the progress begun in 1988 to move towards more efficient and effective support of its clients. This year saw two important steps towards improving the quality of the administrative computer applications developed, maintained, and supported by ASD.

The first step was the adoption of the Productivity Plus[®] systems development methodology. This methodology, which was licensed for the entire Institute from DMR Group, Inc., provides a proven set of procedures for application developers to use to create better systems more efficiently. A number of the ASD staff were trained in the use of the methodology, and it was applied on a prototype basis in conjunction with a computer-aided software engineering (CASE) tool to perform a preliminary analysis of the Property Office. The use of the methodology and CASE tool was well received by both ASD and the Property Office staff, and both are slated to be implemented on more ASD projects in fiscal 1990.

The second step was the development of the *ASD Quality Assurance Standards Manual*, a comprehensive collection of guidelines covering the entire systems development life cycle, from analysis through production. The *Manual* was developed by a group of staff members from ASD and Operations and Systems, with assistance from other departments in IS. It will be used by all ASD staff and, in conjunction with Productivity Plus, will provide them with the information necessary to ensure that all applications are developed and supported in conformance with established standards. During the next year, the *Manual* will be offered to the other application development groups around the Institute.

ASD also made great strides during the year in increasing the skill levels of its staff through training and professional development. In previous years, training in current systems development techniques and management practices had been somewhat neglected. This year ASD provided over 500 person-days of training and professional development for its staff, an average of 13 days per employee. In addition, ASD sponsored an additional 125 person-days of training for client staff as well as others in IS. This training will help prepare us for using new technologies and tools in applications development.

Key milestones accomplished on projects during the year included:

- ASD completed the VS1 Conversion Project in January. This project, which involved staff from ASD, Operations and Systems, and client offices, converted over a dozen key administrative applications from an obsolete IBM mainframe operating system to the current operating system, VM/CMS. The project took approximately two years and required 11 person-years of IS staff effort.
- Last summer ASD performed a functional analysis of the freshman admissions process that resulted in a 100 page report with findings and recommendations concerning the organizational, procedural, and functional operations of the Admissions Office. The Admissions Office adopted many of the recommended changes, and the report will be used to evaluate and prioritize future changes to the existing admissions system.
- As the Institute entered the heart of the \$550 million Campaign for the Future, the existing Alumni, Donor, Development, and Schools (ADDS) system was stretched to its limit in supporting the volume of information requests from campaign and alumni workers. In order to improve the performance and lengthen the life of the ADDS system, ASD and the ADDS clients initiated a project in February to make important efficiency and functional enhancements to the existing system. This one year project will improve the operational efficiency and maintainability of the system and ensure that it continues to meet the needs of the Campaign.

Activities in the last two years have established a solid point of departure for shaping ASD as an efficient and effective provider of applications development and support services to the Institute's administrative activities. We will continue to work closely with our clients in fiscal year 1990 to ensure that the Institute's administrative applications effectively support its research and educational missions.

DONALD E. HELLER

ARCHITECTURE AND STRATEGIC TECHNOLOGIES

The second year of operation for the newest and smallest department in IS, Architecture and Strategic Technology (AST), has been active and productive. AST was formed in 1987 to fulfill a staff function within IS: do the groundwork necessary for the Institute to capitalize on advances in information technology that represent major change and that cross organizational boundaries in new ways.

AST's style is collaborative and practical. We work with other Institute units to address real business needs, building and evaluating working prototypes of potentially large facilities. In doing this, our aim is technology transfer. We support other departments' efforts to transform our successful prototypes into products, services and programs.

In pursuit of a system architecture for coordinated computing, we have been investigating a fundamental question: how do we deliver information from a central office or department to the rest of the campus community. Since most central office information is stored on centrally managed mainframes, we began there with the MIDAS project, which ran the complete course this year from back of the envelope sketch to production service and user support. MIDAS – MIT Information Distribution and Access System – is a service, offering secure access to files produced by central offices and transferring data from them to pc's, Macintoshes, and other workstations on the desks of administrators in departments, laboratories and centers. The first files available from MIDAS are accounting information from the Comptroller.

A second activity for AST during the year was work with the Office of Career Services (OCS) to make available to the Athena user community in the fall of 1989 inquiries to a new database about recruiter visits. OCS will also use the database to support the functioning of its office. This project, in addition to delivering a product, has provided an opportunity to explore the promise of the Athena environment for delivering future Institute-wide applications.

As we explored the topic of public databases, we came to realize that the person at the workstation probably needs access to more than one set of institutional information and may want to combine information from several sources in new ways. Yet it seems impractical to consider storing all such information in one place. This spring AST began work on prototypes of both browsing and authoring functions for relatively unstructured and geographically dispersed data of broad interest, such as policies and procedures, schedules of events, and newsletter articles.

Acquiring applications that fully use the distributed computing environment will entail a substantial investment of resources. Regardless of whether the applications are developed inside or acquired from outside vendors, the quality of applications and the productivity of efforts to deliver them are important factors. This year AST worked with managers and developers in ASD and in the Comptroller's

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Accounting Office to introduce a system delivery methodology called Productivity Plus, from The DMR Group, Inc. Begun last summer, the Methodology Introduction Project (MIP) provided training and support for initial projects and evaluated the methodology's impact. The MIP team's recommendation this winter to use the methodology on new projects in 1990 was accepted, and preparations for that extension are proceeding.

AST's work this year on policies that promote effective management and use of information resources has occurred primarily as an outgrowth of the information delivery and methodology projects. To make the MIDAS service available to administrators, Institute policies about their access to mainframe computing have been modified. Management practices under consideration for evaluating proposals for new administrative systems will rely for pertinent information on all projects adopting the methodology.

Policy making and standards development for distributed information systems is a new venture with which many institutions are struggling. Earlier experience with standards for data processing is not a particularly helpful precedent. Today we need policy making processes that keep up with technological change. Central control of all resources won't work, but dispersing the resources introduces other problems of coordination and prioritization. The Institute needs to agree on what central and distributed information resources are critical and on how it will monitor effective management of them. All those whose decisions and actions affect the availability and protection of information the Institute values need to share an understanding of basic principles and direction.

MARILYN A. McMILLAN

INFORMATION SERVICES

Information Services continued to expand its range of products and services delivered to the Institute community this year.

The Microcomputer Center is in its fifth year of operation. Gross sales for fiscal 1989 are over \$9 million and we expect fiscal 1990 to surpass this figure. We moved to a new facility in the Stratton Student Center which provided us with an opportunity to provide several new services and improve the quality of existing services. The Service Center is now located within the Microcomputer Center providing rapid maintenance and repair service. We have added the NeXT computer and accessories to our product line. We deliver and set-up computers in departmental offices within a twenty-four hour period and personal purchases can be picked up on the day ordered.

Training Services expanded its activities to include thesis preparation workshops for graduate students, several hands-on programming courses, and use of a small library of self-paced training materials. All of these activities were offered in the Microcomputer Training Lab. In our Training Lab, we trained over 1000 MIT personnel in introductory and advanced hands-on hardware and software courses, Administrative Workstation training sessions for new computer users, two-hour Institute Business Modules designed to teach staff to accomplish MIT-specific administrative tasks via computer, and courses designed for individual departments. We held our third year of quarterly noontime seminars which continued to be popular and drew over 2000 attendees.

Consulting Services has increased its expertise and services in the areas of electronic publishing and local area networks. We have continued to form and support user groups and have recently formed a partnership with experts in departments through the Tech Partners program.

The VAX Resource Center (VRC), in its second year of operation, increased its client base during fiscal 1989, providing discounted DEC maintenance services for 300 DEC CPUs on campus and discounted software licenses and update services for 135 DEC CPUs. These figures represent 20% and 75% growth, respectively. The VRC's fiscal 1989 revenue was approximately \$1 million. A focal point for software acquisition was established in Vendor Services with the hiring of a Software Acquisition Coordinator. Vendor Services also started a software update distribution service for users of Sun Microsystems workstations to serve MIT's rapidly growing Sun user community.

Publication Services broadened its promotional activities by developing several brochures and fliers to market IS services, including the *Guide to Information Systems*. We also produced ten issues of *i/s*, the IS newsletter, and a brochure containing computer security tips. We continued to help people become self-sufficient in their computing activities by expanding our series of Quick Reference Guides and Reprints. We also produced our usual technical memos, including User Guides for the Administrative Workstation project and a User's Guide for the Comptroller's Office. We are working to gather data and to produce a catalog of hardware and software at selected sites at MIT.

STEPHEN M. BAYLE

OPERATIONS AND SYSTEMS

During fiscal 1989 Operations and Systems (O&S) concentrated on the installation of new equipment and related activities. O&S has as its mission the goal of providing quality data processing services at an effective cost while achieving recognized improvements in the efficient use of central machine capacity. We feel that we have made major strides toward fulfilling that goal during this year.

A major accomplishment was the merger of the client workloads that were previously on two machines – MITVMC, an IBM 3083, and MITVMD, an IBM 4341 – onto a new IBM 3090 now called MITVMC. This has doubled our data processing capacity and has significantly improved the response time of many activities. Combining the workloads also simplified the background tasks of maintaining systems code and libraries both on the part of the systems programmers and the clients' maintenance staffs. This new system with increased computing power also afforded us a 10% cost savings over old configuration.

A secondary impact of this conversion was the ability to replace the IBM 4381 computer – MITVMA – with the IBM 3083. This doubled the capacity on MITVMA and positions us to better serve the general MIT community. This machine will act as a file server to the Cray 2 computer being installed this summer. Over the next year, we will investigate other projects to exploit the power of MITVMA.

As part of the communications upgrade begun last year with the installation of the NCR/Comten communications processor, many of the old terminal controllers were replaced. This has substantially improved the reliability of our IBM terminal network.

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We have also installed new IBM cartridge tape drives and will be making them available to our client community next year. Also, we have begun to evaluate a new IBM printer which we plan to use to provide more immediate access for smaller print jobs in E19.

A substantial effort was required to prepare for the installation of the Cray 2 computer being leased by the MIT Supercomputer Facility. The Cray 2 was installed in July 1989 and will be housed in W91. It will be maintained by O&S under a facilities management agreement.

During this year, O&S assumed support responsibilities for MIDAS. This system was developed by AST as a prototype to investigate means to deliver mainframe data to personal computers.

Some progress has been made on phasing out the VS1 operating system which runs under VM. The work that previously had run under VS1 on MITVMA has been converted to run under CMS and VS1 no longer runs on MITVMA. On MITVMC, two systems remain under VS1 – the Physical Plant system and the Student Information system. New systems are being developed to replace both. The new Plant system will be in operation in fiscal 1990. However, the student system will likely not be completed before fiscal 1993.

MIT has joined IBM's Higher Education Software Consortium. This provides access to a large number of IBM's software products for a fixed cost. This has provided substantial cost savings for not only the data center, but also for some of the other IBM sites on the campus.

O&S currently employs ten minorities (four on the administrative staff) in its staff of 66. This number did not increase during the year even though the search process for new staff was changed in an attempt to attract additional minority candidates. New position postings are sent to twenty-four agencies and associations which provide information about job openings to the minority communities. In addition, ads have been run in "Black Issues in Higher Education" and the "Boston Globe." O&S continues its commitment to minority employment and its search for new approaches to increase minority representation on its staff.

ROGER A. ROACH

TELECOMMUNICATIONS SYSTEMS

MIT's AT&T 5ESS switching system was placed into service in two phases during fiscal 1989. The first phase occurred during the weekend of August 12, 1988 when the resident student analog telephone lines were placed into service and the Dorm Line telephone system was discontinued. The second phase occurred during the weekend of October 28, 1988, when academic, research, and administrative analog and digital telephone lines were installed and the Centrex telephone system was discontinued.

Individuals with telephone difficulties logged an average of 600 trouble reports per day during the week following the final phase of introducing the 5ESS into service. This number declined to an average of 40 reports per day by the end of December 1988. The number further declined to an average of 20 per day at the end of the fiscal year, a third less than the average number of trouble reports we experienced in the last year of the Centrex system's operation.

MIT officially accepted the 5ESS from AT&T on February 10, 1989, at which time MIT assumed ownership as well as operational and administrative control of the system.

There are currently 12,782 telephone lines working on the 5ESS, of which 8,528 are analog lines, including those provided to resident students, and 4,254 digital ISDN (Integrated Service Digital Network) telephones. Reportedly, the MIT 5ESS is the largest ISDN system in the country at this time.

Voice mail was introduced to the MIT community coincident with the second phase of the cutover of the 5ESS. There are now 2,948 voice mail subscribers. Use of voice mail goes beyond just answering unattended telephone lines. For example, in May 1989, the Benefits Office in conjunction with Telecommunications Systems introduced BenTalk, an interactive telephone service which provides members of the MIT community with access to information about MIT's benefit plans 24 hours a day.

On November 2, 1988, a virus invaded the Internet, the main computer network used by the U.S. research community. The MIT campus computer network is part of the Internet. The rapid diagnosis and elimination of the virus was due in part to the joint efforts of the Telecommunications Systems' Network group, members of the Student Information Board (SIPB), the Laboratory for Computer Science, and their counterparts at the Lawrence Livermore National Laboratory and the University of California at Berkeley. A paper: "With Microscope and Tweezers: An Analysis of the Internet Virus of November 1988" was coauthored by Jon Rochlis, of the Network group, and Mark Eichen, then a student at MIT and a member of SIPB. The paper was accepted for publication in the proceedings of the 1989 IEEE Symposium on Research in Security and Privacy.

During the year, the number of hosts on the campus computer network grew to approximately 2,800. The Network group along with the Transmission group and others in IS are participating in the development of an IS supported campus-wide electronic mail facility. As part of this activity, work is currently underway to provide electronic mail delivery from a post office server to Macintosh computers. For this purpose, the Macintoshes will be connected to the campus computer network via the digital ISDN telephones.

A Ku band downlink satellite dish was installed on top of Building 9. Programs received by means of the downlink are distributed to the community via the MIT Cable Television network. During the year 264 new video cable drops were installed. Also, the Transmission group installed fiber optic links in a number of on-campus buildings for use by Project Athena, and others, and completed a total of 147 Appletalk and Ethernet LAN jobs, and 160 jobs for clients wanting point-to-point facilities, RS232 and IBM3270 connections, etc.

MORTON BERLAN

SENIOR VICE PRESIDENT

This year the Institute continued its commitment to energy conservation, with its attendant cost avoidance, by implementing a shared savings electricity conservation program in conjunction with Cambridge Electric Light company. During the year, five energy service companies (ESCO's) retained by MIT installed conservation equipment and systems with a value in excess of \$4.3 million at no front-end cost to the Institute. Savings of some \$700,000 annually are currently being realized after shared savings payments of \$1.2 million have been made to the ESCo firms. The shared savings payments will continue for four to five years, after which time all savings will accrue to the Institute.

Major design and construction activities this year included completion of the renovation of the lower floors of the Julius A. Statton Center, commencement of the conversion of an existing mill building complex located at 143 Albany Street into a 190-bed graduate student residence, the long-awaited beginning of construction of an addition to the Rotch Architectural Library, and retention of an architect to begin design of a new biology building that will be located on a portion of the former TRW/Carr Fastener site at the corner of Main and Ames Streets. In addition, alterations of the east wing of the Nabisco Building for the Alcator C-Mod research cell and associated support facilities were completed as were renovations of the former bar and Riverside Lounge at the Faculty Club.

Affirmative action efforts continued this year. As reported in prior years, the main thrust of our efforts is to attract more minorities and women to administrative staff and management positions and to attract women to the various trades which have been traditionally male dominated. This year our first female painter was employed by the Physical Plant, joining the female locksmith and first-class firer hired last year. In addition, of the nine administrative staff openings filled this year, three were filled by underrepresented minorities and two by women. While these results are encouraging, nevertheless, much remains to be accomplished and we are committed to continued aggressive action on the affirmative action front.

Following are individual department reports.

WILLIAM R. DICKSON

Campus Activities Complex

This year marked the continued evolution of the Campus Activities Complex as both a department and a program. The completion of the renovation of the basement through third floors of the Stratton Student Center was, without a doubt, the central accomplishment of the year. The phased re-opening of the building resulted in the availability of 13 returning or new business services; upgraded and relocated MIT Food Services; new Student Center Committee 24-hour coffeehouse and gamesroom facilities; and attractive, responsive facilities for meetings, events and conferences.

Concurrent with the completion of the major Stratton Student Center renovation were a number of other renovation projects within the complex including completion of the renewal of the reverberation system in Kresge Auditorium, expansion of space for Project Athena and the Dean for Student Affairs, and the selection of a design firm and client team to address handicapped access concerns within Kresge Auditorium and MIT Chapel.

In conjunction with the Office of the Dean for Student Affairs, the final phase of staff and program reorganization was initiated with the transfer of responsibility for several student activities and programs. Initial emphasis has been to assist these groups with improving their overall effectiveness while also reviewing internal procedures and financial operations.

The directorship of the department changed with the promotion of Stephen D. Immerman to Director of Special Services in the Office of the Senior Vice President. Following a national search, Phillip J. Walsh was hired as the new Director. Administrative and managerial activities continued to reflect an evolving organization committed to providing quality service and support to the MIT community.

During the year, the Advisory Board of the Campus Activities Complex was charged with the mission of developing and maintaining the use of the Campus Activities Complex as a center for social, cultural, educational and recreational interaction beyond the traditional classroom environment while also being a center for conveniences and amenities for students, faculty, staff, alumni, and guests of the Institute. The Board will endeavor to create an atmosphere within the complex which enhances enjoyment of life by members of the MIT community.

PHILLIP J. WALSH

Campus Police

The MIT Campus Police Department continued to serve the community with 24-hour professional police and emergency medical services. In addition, the Crime Prevention Unit and Special Services Division continued to assist the MIT community by providing crime prevention education; informal legal advice; and assistance for minor legal problems of extenuating circumstances such as landlord/tenant disputes, consumer fraud, small claims court cases, and abuse and harassment situations.

There were a total of 1,552 complaints (situations which required the recording of an incident by a police report) recorded this year, a 4 percent increase over last year. Of these 1,552 complaints, 23 were in the crimes against person category. Campus Police officers made 76 arrests on MIT property this year.

Larceny continued to be the largest category of crime with which the Institute had to contend again this year. Although the total number of reported incidents was down 12 percent at 135, total dollar losses were up 30 percent over last year at \$354,587. Computers and computer components were, once again, the most frequently stolen type of Institute-owned property.

Personal property (non-residence) thefts were up 33 percent with a total dollar loss of \$26,337. Wallets and purses led the list of items stolen.

The number of residence hall losses was down 55 percent with a total dollar loss of \$11,670. This dramatic reduction was due, in great part, to the implementation of an expanded dormitory security program.

Motor vehicle thefts increased 50 percent this year for a total of 30 vehicles stolen.

Emergency medical services decreased 13 percent this year for a total of 2,078 runs (including emergencies, transfers, and medical shuttles).

The Campus Police escort service provided 6,126 escorts this year, a decrease of 1 percent over last 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

Marketing continues to be a major priority particularly focused on attracting residential business as opposed to day groups. Initial results from the direct mail campaign have indicated an encouraging response. In conjunction with the marketing campaign, eight rooms in the Brooks Center were renovated to reflect the same elegant style and charm as the guest rooms in the main house. Further rooms are scheduled for renovation next year.

Funding for capital improvements continues to present a major challenge. Improvements made this year include asbestos removal, exterior painting, bathroom renovations, refurbishment of furnishings, and the purchase of a station wagon and log splitter. Several large-scale projects that remain are enclosing a back staircase to provide a means of emergency egress and designing a new septic system for the manager's residence.

This year's spring Senior Executive Program, the 66th session conducted to date by the MIT School of Management, set a new level of excellence in service by the Endicott House staff. The food, housekeeping, and overall accommodations were consistently ranked in the highest categories by every respondent of the evaluation questionnaire.

In an effort to maximize summer business and in response to day groups requesting use of recreational facilities normally reserved for residential groups, a new day program is being explored which would combine a work session with a recreational outing.

The Endicott House Board of Governors met at a special meeting in the spring to discuss the eventual transfer of the Stearns Estate to MIT. It appears that the estate will be settled this year. A tour of the house and property was conducted, followed by a discussion session to explore possible uses of the facility. It was the consensus of the Board members that this gift represents a unique opportunity for MIT and various options for its use will be investigated.

From a statistical standpoint, Endicott House continues to be utilized by both MIT and non-MIT groups, for both day business and residential groups. Throughout the year, Endicott House and the adjoining Brooks Center were used 275 days and 176 nights by 199 groups. This compares with 254 days, 179 nights, and 196 groups the previous year. Of these groups, 81 were affiliated with the Institute and 118 were non-MIT groups. There were 30 overnight conferences ranging in duration from one night to the Sloan School's nine-week Senior Executive Program. Of the resident groups, 16 were from MIT and 14 were non-MIT groups. There were 6,453 room nights used and 25,166 meals served during the year.

HOWARD F. MILLER

Graphic Arts and Audio Visual Services

Total income for all Graphic Arts services was virtually unchanged from last year at \$6 million. The volume of work in Illustration Services declined by 25 percent due to the increase in use of personal computers. Audio/Visual income increased 12 percent.

Video Production Services, which proved its viability during a two-year trial period with Graphic Arts, was consolidated with the MIT Center for Advanced Engineering Study (CAES) during the year.

A new copy center was opened in the recently renovated Stratton Student Center, offering rental of time on personal computers, use of Telefax machines, and 24-hour coin-operated copy machines as well as conventional copy center services.

The most significant equipment purchase was a new computerized student identification video system which provides a digitized color printed identification card while the individual waits and is also capable of producing multiple black and white laser prints for classroom use. It is expected that this system will also be used for MIT employee identification cards.

JAMES W. COLEMAN

Housing and Food Services

Security continues to be a major priority for the department. To help ensure the safety of students living in the housing system, a training program was conducted by the Campus Police for all night watchmen; night time security coverage was expanded to include the summer months; and House Managers continue to develop and implement security awareness programs in their individual residences. These programs helped reduce the theft rate in dormitories by 55 percent this year.

Renovation of a new graduate student residence at 143 Albany Street commenced this year. Approximately 190 graduate students will be accommodated upon completion of this project in January of 1990. Revised graduate housing policies and procedures were developed to address the issue of housing more first-year graduate students upon the opening of this new facility.

In addition to the regular maintenance projects, several other significant improvements were made including redesigning and upgrading the East Campus Munroe entry bathrooms, caulking and waterproofing two elevations of Eastgate and Westgate, and renovation of the last two tutor apartments in Baker House.

During the year, the Food Services management critically evaluated current programs to assure that MIT goals are achieved and the food service needs of the community are being adequately served.

As part of the new Stratton Student Center, a totally renewed Lobdell opened in September. The food court concept features many different varieties of food in an open serving area. Networks, a fresh seafood restaurant featuring table service, take-out service, and catering, opened in December.

The Faculty Club underwent major renovations this year. Improvements include new banquet facilities for catered events and meetings, a la carte and buffet dining in newly renovated dining rooms, and a comfortable bar service area. A computerized reservation system will become fully operational this fall.

LAWRENCE E. MAGUIRE

Office of Facilities Management Systems

The Office of Facilities Management Systems (OFMS) facilitates the development and application of facilities management software through the MIT/OFMS INSITE system and has fostered the transfer of technology through the Consortium of INSITE users and various educational programs. The office is responsible for maintaining the INSITE space accounting system, which tracks the Institute's 9 million gross square feet of space and annually audits MIT's physical space and maintains a current space inventory on its database, along with electronically digitized floor plans.

In the past year, two newly-developed software packages, CADVIEW and CADLABEL, have become available to the MIT community. CADVIEW allows the viewing of digitized floor plans of campus buildings and rooms and FIXLABEL, a feature used with CADVIEW, permits the writing and saving of text on floor plans. Several departments have participated in the development of this technology.

Over the year, the INSITE Consortium added 16 different sites where INSITE is used. Applications support continues for all consortium members via telephone, member visits to MIT, site visits by OFMS staff, and an annual workshop.

Other educational functions carried out by OFMS during the year included the founding of the International Society of Facilities Executives (ISFE) which was created to address the needs of the senior facilities executive. The office also conducted an intensive three-week course for Japanese executives which was sponsored by the Japan Facility Management Association (JFMA). The course was jointly presented by OFMS and the School of Architecture and Planning and the JFMA has asked that the MIT program be repeated for three years.

KREON L. CYROS

Physical Plant Department

Fuel Prices

This year a measure of stability returned to energy pricing in the northeast. With the exception of a brief bulge in oil prices following the Alaskan oil spill, the fuel oil and gas price fluctuations followed normal seasonal patterns. Overall energy prices dropped 10 percent below last year's levels. As a result of this record of moderation and apparent stability in energy pricing, the energy budget proposed for next year was adjusted downward by 8 percent.

Electric Power Rebate Program

The Cambridge Electric Light Company introduced a shared savings electric energy conservation program last year and Physical Plant, seeing the broad advantages of the program with its attractive cash rebate initiative, set in place a program to introduce many more cost effective energy conservation measures into our academic and residential buildings. This program has more than realized our expectations. In 12 months of intense renovation activity, working in almost every office and laboratory, five energy service companies (ESCO's) employed by MIT have put in place conservation equipment and systems with a value in excess of \$4.3 million; at no front-end cost to the Institute. These alterations are now returning some \$700,000 annually after shared savings payments of \$1.2 million have been made to the ESCo firms. The shared savings payments will continue for four to five years after which time all savings will accrue to the Institute. The final scope of the program, when it is closed out early next year, seems sure to exceed original expectations by nearly 25 percent. Our annual electricity demand and power purchases will have been reduced by between 10 and 15 percent; good news for the Institute, for the Cambridge Electric Light Company, and for the entire northeast power region.

Cogeneration

The year closed on a positive note for the long-proposed Institute cogeneration project. After nearly a year of preliminary planning, study, negotiation, and design scrutiny, the project has met each of the feasibility criteria established by the administration and was released in June for public exposure and the start of the environmental permitting process required by federal, state, and local regulatory agencies. The permitting process will continue for the better part of a year, to be followed by design and construction. The first benefits in reduced and stabilized energy costs may be realized as early as fiscal year 1993. The target of the \$23 million project is a 10 to 15 percent reduction in the Central Utility Plant energy budget. The new plant, which will replace the two oldest boilers in the Vassar Street power station, is described as a combined cycle cogeneration plant. The configuration now foreseen is a 22-megawatt combustion turbine fueled by natural gas, exhausting to a heat-recovery steam generator, and a 3-megawatt steam-turbine generator. Heat in the exhaust gases from the combustion turbine electric generator will produce steam for MIT's heating and cooling needs. The electrical energy produced will be the main supply for all campus needs.

Water Conservation

Water conservation has been widely publicized as a serious need in eastern Massachusetts. This situation was highlighted by the water use restrictions put in place this spring in all metropolitan areas. As a further incentive, the newly constituted Massachusetts Water Resources Authority is rapidly escalating water and sewer rates to make sure the proper economic signals for conservation are sent to the commercial and industrial community. Water cost will shortly move up to challenge fuel and electricity as the major items in the Institute's utility budget. Pushed by these pressures for conservation, the Institute is moving to reduce its water use by at least one-fourth with a broad conservation program patterned on the successful energy conservation programs of recent years.

Computer Support

During the year, the first substantial results were seen in a program to expand Physical Plant's use of personal computers in building design, construction, renovation, space change, and data maintenance activity. This use of personal computers is seen as supplementing and complementing the departmental use of large computer systems to process physical plant management information. In cooperation with the Planning Office and the Office of Facilities Management Systems, the Institute's floor plans, building and underground utility systems drawings, and the survey plans of the main group area of the Cambridge campus have been converted to digital format and electronic storage. CADD techniques are now used extensively for normal design and drafting activity.

The first module of the new Physical Plant on-line management information system went into operation in October, 1988. Plant personnel are now logging trouble calls and dispatching workers through the new system. Work orders are being issued and traced by computer. Managers have on-line access to view current workload and work order history. The Preventive Maintenance (PM) module, which will automatically produce scheduled PM work orders, will be operational next fall. The labor module, which will track labor costs and integrate with the Institute's Payroll System, is currently under development and is scheduled to be completed late next fall.

Facilities Construction and Renovation

The major renovation of the lower floors of the Stratton Student Center for new commercial and dining space was completed in the fall of 1988. Construction was started last winter on the 190 bed graduate student housing facility at 143 Albany Street. An old brick mill building, the complex is being completely renovated to include 87 air-conditioned apartments along with meeting rooms, an exercise room, laundry facilities and storage. Renovation was also started in December on the easterly portion of the Faculty Club. The bar and Riverside Lounge were replaced by two dining areas, an entry lounge, and a servery in order to meet the need for more function space. Refurbishing of the main dining room and elevator lobby this summer will complete the project.

Construction of an addition and renovations to the Rotch Architectural Library were started in May. The addition will primarily house book stacks and the renovated space in Building 7 will house the circulation desk, reading room, and other library activities. Occupancy is scheduled for fall 1990. The program for the new Biology Building to be located on a portion of the former TRW/Carr Fastener site was completed during the year and an architectural design firm selected. The Client Team for the building has been meeting regularly and the current schedule calls for construction to begin in mid-1990.

During the year, alterations were completed in the Nabisco Building for the Alcatraz C-Mod research cell and support facilities. A new video production facility with state of the art equipment and services was constructed in Building 9 for the Center for Advanced Engineering Studies. The last of significant laboratory renovations were completed for the Biotechnology Process Engineering Center in Building 20A. The Alumni Pool building was the scene of considerable activity during the year with the creation of a large new women's locker area, rejuvenation of the squash courts, and replacement of the roof. Building 14 was also the scene of a concentrated summer effort to provide air conditioning and refurbishment of the north wing for Humanities prior to the start of fall classes.

On the East Campus, the Cancer Research Center consolidated its glasswashing facilities in E18 space formerly occupied by the Housing and Dining office which completed its move to E32. Building E10, was refurbished with some windows added, and former animal labs space on the third floor converted into faculty offices for the Department of Brain and Cognitive Sciences.

Building Operations

A comprehensive water treatment study was completed for both the Central Utilities Plant and individual building systems. As a result, proposals were solicited and a contract awarded to a new single water treatment vendor servicing the entire campus.

A facilities audit of all animal care spaces was conducted during the fall. All major deficiencies and most minor problems have been corrected. A complete report on these facilities will be made to the Director of the Division for Comparative Medicine in the near future. A review of the Preventive Maintenance master schedule was started this year with the objectives being to eliminate unnecessary tasks, assure that all necessary maintenance is properly scheduled, and improve the efficiency of the overall program. It is expected that this will take two years and will continue through the transition to the new plant system PM module.

Grounds Services continues to upgrade and improve the campus environment with selective sodding and an expanded tree maintenance plan. They are also continuing their vehicle and equipment replacement programs. Lawn

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irrigation systems were installed in Killian Court and the large court between the Weisner Building and Health Sciences and Technology complex. The Ford Parking Lot and the Main Lot Annex were graded and resurfaced. Buildings E52 and 14 received new roofs. Spalling limestone along the Building 3 east facade was cut out and replaced.

Building Services reviewed and updated their training programs which are given to all new employees as well as refresher training for current employees. The Plant convened representatives from a cross-section of the community to begin studying options for modernizing our systems for securing and accessing campus buildings as the dramatic campus growth over the past 25 years has severely strained our existing master key system. A comprehensive proposal to reestablish a waste recycling plan for the Institute is currently being prepared.

PAUL F. BARRETT

Planning Office

The Planning Office's activities this year reflect its continuing efforts to provide the Institute with strong physical planning, institutional research, and community planning capabilities. Several major efforts involved all three aspects of the Office's mission. These included: the Northeast Sector Master Plan, continued preparations for a new Biology facility to be situated on Ames Street using land occupied by the former TRW/Carr Faster Division plant, the renovation of buildings at 143 Albany Street into graduate student housing, the implementation of a strategic plan for integrating Institute information into an effective planning database, and the continuing planning and administrative support for a variety of Institute departments and committees.

INSTITUTIONAL RESEARCH

The effort to develop a more integrated and comprehensive management and planning information system made excellent progress through Phase Two of the Office's three year implementation strategy. The MIT Factbook was revised for FY 1988 and distributed to all departments, and plans are underway for an electronic version. This statistical summary of the principle indicators of institutional growth and change is one of several anticipated planning and reference documents which will be made available to senior officers and to departments, laboratories, and centers.

Ongoing efforts of the institutional research staff include enhancements to the computerized system supporting the Provost's Five Year Planning process, continued development of planning database systems, and the development of an executive information system. Unlike many departments which require data for their own personnel only, the Planning Office has special needs for gathering and analyzing statistical data from across the campus. Incorporating these requirements into developing systems will continue to be a concern of the Office; major issues include system design, standards selection, security and privacy policies, planning for departmental training and support, database implementation and maintenance, and recommendations for cost allocation.

Other major project efforts included a report on occupancy of Building 20, in cooperation with Physical Plant, for the Provost and the Committee for Review of Space Planning, a report on Utilization of Animal Care Facilities; and, in cooperation with the Physical Planning group, a report on the renovation of Building 16, relocation of its current occupants into spaces in Building 56 (to be vacated by the Biology Department), and relocation of certain Physics Department activities into a renovated Building 16. Members of the Institutional Research staff also provided a significant degree of support to the Committee on Family and Work. This has included the design, data tabulation, and analysis of a set of surveys of members of the Institute community, assistance in negotiating and managing an operating budget for the Committee, and research related to various policy issues.

In a continuing effort to stay abreast of issues and activities at other universities, the office hosted the third annual conference of the Ivy Plus Institutional Research Association. In addition, the Institutional Research group made presentations at several national conferences. The Planning Office sponsored a national conference on faculty housing resources and development strategies in cooperation with Harvard University.

PHYSICAL PLANNING

A major planning effort was begun in the spring of 1988 with the initiation of the Northeast Sector Master Plan, covering the area of the main campus bounded by Main Street, Ames Street, buildings 16/56/66, buildings 26/36, and Vassar Street. This quadrant will also house a new Biology facility to be located along Ames Street adjacent to building 66 and preliminary planning is underway for that building. The results of this work include a full report which addresses a range of planning issues and the forthcoming publication of a summary document to be used for information and fund-raising purposes.

Other planning efforts included a study of renovation and re-use options for 311-312 Memorial Drive (Buildings W2 and W2A) as undergraduate women's housing and the continuing review of housing site alternatives for students, faculty, and staff; exploring methods for expanding opportunities for sororities and other independent residences; and design

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alternatives to relieve campus parking problems. In addition, the Rotch Library expansion, a Classroom Priorities Plan and Design Study, and a major Performing Arts Study have occupied staff attention, as have development trends in the Westford area and review of the handicapped accessibility program.

Efforts to improve the MIT landscape, as well as service access and pedestrian circulation, continued in cooperation with MBTA and the City of Cambridge. Ongoing concerns include a pedestrian crossing at Ames Street, interim development of property on Main Street adjacent to the Kendall Square MBTA station, and consultation on planning and development of the Stratton Student Center area. In an effort to increase productivity within current staff levels, the campus base map has been digitized and the office is increasing its use of computer-aided design and drafting (CADD) techniques.

COMMUNITY PLANNING

Events in Cambridge required our attention and coordination of efforts throughout the year. The continued development of the Kendall Square urban renewal project has had an impact on the Institute's immediate environment. Current planning includes proposed residential and commercial facilities on a remaining parcel adjacent to the Whitehead Institute. Meanwhile, the City of Cambridge has presented zoning proposals to reduce the allowable building height and capacity limits in areas surrounding and including the Main and East campus. We are now engaged in an evaluation of the impact on MIT of these proposals

The University Park project on the former Simplex property continues to be a major focus of activity. Continuing concerns include the effects of the environmental impact statement filed by Forest City Enterprises, developer of University Park, on traffic patterns and the quality of life in that area. In addition, a proposed truck route through the city via Vassar Street would create significant problems for on-campus residential development planned for that area on the West campus. We continue to monitor the Massachusetts Avenue and Harvard Bridge projects as well as many zoning and land use policy issues raised by community groups in Cambridge.

O. ROBERT SIMHA

Safety Office

Introduction

This year marks the implementation of the Institute's self-insurance program for Workers' Compensation. It appears this program will be both effective in reducing costs and in improving efficiency.

Education and Training

Various educational and training efforts were conducted this year including the introduction of safety seminars for support staff, student-run fire prevention programs, and high-rise safety seminars in Ashdown House and MacGregor House. Evacu-chairs were purchased for the handicapped by the Medical and Housing departments and training programs were conducted on their proper use. The Federal Hazard Communication Standard was expanded to cover MIT and guidelines on how to comply with this standard were distributed to all departments and laboratories. The MIT Accident Prevention Guide was revised and will be published next fall.

Hazardous Materials

The implementation of a policy requiring hazardous chemicals to be transported in break-resistant containers was a significant safety improvement. A computerized inventory system of hazardous chemicals is currently being developed by the Safety Office, Environmental Medical Service, and Purchasing. This system will improve reporting procedures required by several state laws.

New procedures were implemented for handling compressed gas containers in corridors and non-returnable compressed gas cylinders.

The volume of disposal of chemical waste continued to grow. Disposal of polychlorinated biphenyls (PCB's) doubled over last year's volume.

Laboratory Safety

An emergency equipment and supply station has been established in Room 8-023 to handle special emergencies that occur on the main campus. The unit will be fully operational early next year.

Most departments with laboratories have now completed Emergency Action Plans.

Fire Protection

The High Rise Sprinkler program continues to make slow progress due to various fire code interpretations. Extensive fire protection work such as plan reviews and fire pump and fire alarm installations was completed at Endicott House, the Central Utility Plant, the Faculty Club, and in Buildings 7, 13, NE43, and W20.

The number of fires at MIT remained the same as last year (28) but our control of false alarms improved significantly. There were no large fire losses this year.

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Safety Audits

An inspection of three MIT machine shops was conducted by the Occupational Safety and Health Administration. As a result, all machine shops were advised of the violations noted and advised how to correct them.

JOHN M. FRESINA

VICE PRESIDENT AND TREASURER

INTRODUCTION

The programs and other activities related to the Campaign for the future continued at a high level. The Campaign kickoff events and a large number of other events were held in several cities during the year. The process of cultivation and involvement of individuals continued and the solicitation of individual prospects increased. Development activities related to both corporations and foundations were reorganized and expanded. During the year, the Campaign total of gifts and pledges increased by \$103.2 million. This increase brought the total to \$417.4 million which is \$100 million higher than expected at this time when the goal of \$550 million by June of 1992 was set. Since the Campaign was announced on October 22, 1987, the Campaign total has increased by an average of \$10 million per month as compared with our expectation of \$6.5 million per month. The success and growing confidence of our staff and volunteers provides optimism for a continuation of our present rate if the economic environment remains favorable.

The two major activities of the department are divided into Resource Development-Gifts, and the Industrial Liaison Program within the Corporate Relations group. The reorganization of our overall corporate relations program should provide corporations with a more coherent way to develop and maintain relations with the Institute and its faculty and staff. Such relations take a wide variety of forms, including the Industrial Liaison Program as one with particularly widespread involvements both within and outside MIT. An improvement in our coordination and understanding of these relationships should favorably affect both those companies with many forms of interaction and those with more focused involvements.

Staffing for the Campaign continued during the year and resulted in hiring 6 new staff members and the transfer of 3 MIT staff to Resource Development. David Lundberg was hired as Director of Development for the School of Humanities and Social Science in September 1988; and transfers to Resource Development on July 1, 1988 were Barbara Stowe as Director of Foundation Relations, and John Wilson as Assistant Director of Corporate Development. In addition, on October 1, 1988, Eric Johnson assumed the new position of Director of Corporate Relations. This appointment combines into 1 group all corporate fundraising activities including Corporate Development and the Industrial Liaison Program. There were 11 promotions, 6 from support positions to administrative staff. Efforts continue to develop career paths for members of Resource Development which afford opportunities for professional growth and advancement. We also are seeking qualified under-represented minority and women candidates for open positions. Of the new staff joining the department in FY89, 6 were women and 1 was an under-represented minority.

PRIVATE SUPPORT

Private support for fiscal year 1989 totaled \$86.9 million, including the following: \$78.4 million in gifts, grants, and bequests, and \$8.5

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million in fees through membership in the Industrial Liaison Program. The total, which is the second highest in MIT's history, compares with \$91.9 million in 1988, \$76.4 million in 1987, \$62.8 million in 1986, and \$68.5 million in 1985. Gifts-in-kind for the past year (principally gifts of equipment) were valued at \$17.3 million and are not included in the totals.

Sources of gifts for fiscal year 1989 were: alumni, \$30.3 million; non-alumni friends, \$4.5 million; corporations, corporate foundations, and trade associations, \$27.5 million; foundations and charitable trusts, \$15.5 million; and others, \$0.6 million.

Donors designated expendable and endowed funds as follows: unrestricted, \$18.7 million; departments, \$26.5 million; faculty salaries, \$9.5 million; graduate student aid, \$7.4 million; undergraduate student aid, \$4.2 million; building construction funds, \$1.1 million; and other funds \$11 million. A portion of the unrestricted gifts was redesignated to specific purposes by the Institute.

Private Support in 1989 increased the commitments raised for the Campaign for the future to \$417.4 million, representing 75% of the \$550 million goal set for June 1992. By Campaign priority, commitments raised and percentage of goal were the following: Endowment for Faculty Chairs, \$57 million (57%); Academic Programs, \$199.5 million (88%); Student Support, \$54.7 million (45%); New and Renovated Facilities, \$13.6 million (20%); and Unrestricted Gifts, \$73.4 million (183%). In addition, commitments totalling \$19.3 million are pending designation.

MAJOR GIFTS

In FY89, the Office of Major Gifts, directed by H. E. (George) Ramonat, continued its proactive approach toward its prospects. Campus visits, individual visits by senior officers, deans and faculty, and key volunteers, both on and off campus, and small events hosted by prominent alumni continued to be the primary method of making major gift and principal gift prospects aware of the case for MIT's Campaign. Sixty-one solicitations were managed by Major Gifts Prospect Managers - 53 of these prospects were rated at the major gifts level, and 8 were solicited below the major gifts level by senior officers and volunteers as a result of strategies coordinated with the National Campaign Office and the Reunion Gift Program. Gifts resulting from solicitation activity in FY88 and FY89 resulted in \$21.9 million in gifts and pledges for the year, an average of \$592,000, primarily in support of faculty salaries and academic programs.

Significant events managed by the office for the purpose of cultivation and stewardship included luncheons, dinners, receptions and other activities, many in cooperation with the National Campaign Office. Especially noteworthy were the Made in America reception and dinner hosted by Norna Sarofim '72 held at the Plaza Hotel in New York and the I. M. Pei '40 Westchester event at Pepsico headquarters in Purchase, New York hosted by Robert Dettmer '55, coordinated with the School of Humanities and Social Science and the School of Architecture and Planning.

The office took on the responsibility for all National Campaign and Major Gifts activities in the New York Metropolitan area. Margaret Gutowski, former Assistant Director of Major Gifts Research, was promoted to Major Gifts Officer and assigned to the area. Lee-Ann Day was promoted to Associate Director of Major Gifts for regional activities, in addition to her responsibilities for major gifts prospects in Boston and Florida. Lucy Miller was promoted to Associate Director of Major Gifts for Principal Gifts and continues to have regional responsibilities in the Midwest and Southwest. Deborah Cohen, Assistant Dean for Development in the School of Architecture and Planning, was assigned responsibilities as a Major Gifts Prospect Manager for the Western United States, the Middle Atlantic states, Western Pennsylvania and Ohio. Laura Quinn was promoted to Assistant Director and assumed the responsibility of managing the Major Gifts research area. Two new researchers, Marcia Gagliardi and Chrys Miliaris, joined Major Gifts, replacing Julia Bonem and Elsie Kappler.

The research staff supported front-line Campaign activities, including researching and writing the documentation for 61 solicitation plans; 37 cultivation plans; 106 prospect profiles (prepared for cultivational/informational purposes); 46 strategy sessions; 127 qualifications (17 for the National Campaign Office).

Julie Eastman, Assistant to the Director for Donor Relations, continued to work on systematizing the process of writing letters of appreciation for gifts and pledges over \$1,000. She also coordinated with the Corporation and Foundation Relations staff formulating the appreciation process for their donors. During the year, 1,397 letters of appreciation were produced for Dr. Gray and Dr. Saxon, as well as 59 letters for Corporation Development Committee nomination activity.

Major Gifts staff were supported by Elizabeth Gerber and Arthur Fuscaldo.

NATIONAL CAMPAIGN

Building upon the National Campaign Committee volunteer base of 200 alumni recruited in the prior two fiscal years, the emphasis changed this year from recruitment and training of volunteers to the cultivation and solicitation of prospects believed capable of making gifts in the range of \$50,000 to \$500,000. In areas where Campaign kickoffs had previously occurred, Committee members began to host smaller numbers of prospects at dinners and luncheons where an Institute faculty member or senior administrator was the featured speaker. Thirty-two of these functions, including many in cooperation with the Major Gifts staff, were held across the country. Particular emphasis was placed on the major markets of Boston, New York, and Silicon Valley. Volunteer recruitment continued in markets that were more recently organized such as Westchester/Fairfield, Long Island, Pittsburgh, Detroit and Seattle, bringing the total membership on the National Campaign Committee, chaired by D. Reid Weedon, Jr. '41, to 242 by year's end.

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The highlight of the many cultivation events produced this year was Event 128 - A Salute to Founders on April 29. Ninety-nine alumni founders of companies in Massachusetts were honored at a black-tie gala and presented with an MIT Corporation citation for their achievement, as well as a book of individual profiles. The research to identify these founders was part of a larger study conducted by Senior District Director John W. Larson, assisted by several Campaign Systems' staff, which identified 636 alumni company founders in Massachusetts. The data was also used by the Bank of Boston in a study issued in June entitled, MIT: Growing businesses for the future. Publicity regarding citation recipients and the Bank of Boston study resulted in favorable press coverage.

Personnel changes in the National Campaign Office headed by the Director of Campaign Operations, Henry B. Barg, included the following: James N. Phinney, Senior District Director for New York City, announced his retirement in December after 26 years with MIT; Marie J. O'Connor, Senior District Director, resigned in January; Alfred R. Doig, Jr., Senior District Director, resigned his position to become Director of Development for the School of Engineering at MIT; Marilyn K. Kuhar, District Director for Boston and John W. Larson, District Director for Boston and Silicon Valley, were promoted to Senior District Directors; Joy J. Carrigan was hired as District Director for Boston; and Betsy Millard was hired as District Director - Special Constituencies.

Approval to begin a Parents Program was given this past year by President Gray. In cooperation with the Alumni Association, Betsy Millard has been developing a parent relations program, with special emphasis on identifying parent prospects who have the capability of making significant gifts to the Institute. Considerable progress has been made in producing and disseminating informational materials and organizing programs especially designed for parents. A newsletter will be sent to parents several times a year in addition to letters from President Gray and Dean for Student Affairs Shirley McBay, and special complimentary issues of Technology Review. Plans are underway for a Family Weekend on October 20-22.

With the major emphasis in the final 3 years of the Campaign on alumni cultivation and solicitation, the National Campaign Office staff will be responsible for one or more geographic areas. Robert Hagopian, Director of the National Business Committee, has been asked to assist the field efforts due to his many years of development experience and knowledge of the Institute.

Sustaining Fellows and Special Events

Under the direction of Cassandra N. Page, Manager of Sustaining Fellows and Special Events, the Sustaining Fellows brochure was revised and sent in March with an updated membership list of more than 940 members. This mailing included a letter from Dr. Saxon about the Campaign and the October 4, 1989 Sustaining Fellows annual event. By year's end, the membership increased to over 1,000 members.

In May, V. Meredith Thomas, Assistant Manager of Sustaining Fellows and Special Events, sent copies of Made in America to all current members along with an announcement from Dr. Saxon that the October 1989 Sustaining Fellows Event would honor Professor Harold Edgerton. Many enthusiastic thank-you letters were received from members showing a strong support for MIT's efforts to address the national crisis in productivity.

The Sustaining Fellows Memorial Book Program was initiated this year. In cooperation with Dr. Jay Lucker, Director of Libraries, and the libraries' staffs, this program was created to recognize the support of deceased Fellows through the acquisition and dedication of new books. A photocopy of each bookplate is sent to every surviving spouse with a letter explaining the Memorial Book Program. Response from the recipients has been grateful and enthusiastic.

Many Sustaining Fellows were invited to events held on campus and around the United States during 1988-1989 and were included in the total of 830 who attended the following Campaign-related affairs:

California

St. Francis Yacht Club, San Francisco, CA - October 4, 1988
Cocktail reception, program and dinner
Speakers: Paul Gray, John Reed, David Saxon, and Robert Solow
Hosted by the San Francisco Campaign Committee

Ohio

BP America Headquarters, Cleveland, OH - November 15, 1988
Cocktail reception and dinner
Speakers: Paul Gray and Lester Thurow
Hosted by Robert Horton and the Cleveland Campaign Committee

Georgia

Ritz-Carlton Buckhead, Atlanta, GA - February 16, 1989
Breakfast
Speakers: David Saxon and Lester Thurow
Hosted by E. Milton Bevington and the Atlanta Campaign Committee

Boston

75 State Street, Boston, MA - April 29, 1989
Event 128 - A Salute to Company Founders
Cocktail reception and dinner
Speakers: Alexander d'Arbeloff (Event Chairman), Paul Gray, Cecil Green, Norman Leventhal, Patrick McGovern, Kenneth Olsen, and David Saxon
Hosted by Norman Leventhal and the Boston Campaign Committee

Texas

Tower Club, Dallas, TX - May 8, 1989
Cocktail reception, program and dinner
Speakers: David Baltimore, Paul Gray, and David Saxon
Hosted by Walter Humann and the Dallas Campaign Committee

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California

Villa Montalvo, Saratoga, CA - May 9, 1989
Cocktail reception, program and dinner
Speakers: David Baltimore and Paul Gray
Hosted by the Silicon Valley Campaign Committee

Smaller events were hosted by volunteers in locations such as Los Angeles, Houston, St. Louis, Boston, New York City, Palm Beach, Chicago, Silicon Valley, and Long Island.

Campus Visit Program

The Campus Visit Program, under the direction of Estelle Cashman, Campus Visit Coordinator, held 6 campus visits during the year: 3 in the fall and 3 in the spring. The Institute hosted 203 alumni and friends on campus - an increase of 37% over the previous year.

The format for each 36-hour visit was similar: a reception and dinner at the MIT Museum Thursday evening, followed Friday, by a full day of informational programs and dinner that evening at the President's House hosted by Dr. and Mrs. Gray; and a wrap-up breakfast Saturday morning at the Cambridge Center Marriott where the campus visitors stayed as guests of the Institute.

Two of the campus visits had a special non-school focus: the September 22-24 program highlighted the arts, while the November 3-5 program highlighted biomedical research. Both programs encompassed a wide variety of Institute activities.

The MIT Schools of Architecture and Planning (November 17-19), Humanities and Social Science (March 9-11), and the Alfred P. Sloan School of Management (April 27-29) hosted campus visits which gave their guests special insight to their teaching and research programs.

Repeating the successful formula of the previous year, a special campus visit for MIT alumni and friends who are entrepreneurs in high technology fields was held April 13-15. While these visitors had similar interests and their visit was designed to include subject matter of particular concern to the group, the content of the program introduced a wide range of MIT activities and people.

CORPORATE RELATIONS

MIT continues to develop and maintain mutually beneficial relationships with leading industrial corporations around the world. These corporations interact with MIT in a variety of ways, and the relationships which develop are very important to the educational and research mission of the Institute. To better take advantage of these interactions and to make more coherent MIT's relationships to industry, the Corporate Relations Group was formed this past year, gathering within the organization the Industrial Liaison Program, the Corporate Development group, and components of Campaign Systems and Development Services.

For the past 40 years, the Industrial Liaison Program has been a key vehicle for developing corporate relationships with MIT. On October 20-21, the Industrial Liaison Program celebrated its 40th anniversary with a major two-day symposium: "Technology Transfer: Putting Knowledge to Work." The activities of the Industrial Liaison Program frequently intersect with other relationships MIT has with corporations, particularly in the development of support for academic initiatives, funding for faculty and student activities, and in the stewardship of corporate gifts to MIT.

On October 1, Eric C. Johnson was appointed Director of Corporate Relations, following six years as Assistant Dean of Engineering for Resource Development. A number of organizational changes were undertaken in order to strengthen relationships with corporations, as well as to better coordinate a number of services within the Corporate Relations group. Additionally, several fundraising projects involving close cooperation with the Schools were begun, especially with the Schools of Science and Management.

The Industrial Liaison Program had already been organized into 4 groups according to industry sectors. The group leaders: Peter Cerundolo, David Marsh, John W. Leech, and Karl F. Koster have now been named as Managers of Corporate Relations and given broader responsibility for corporate relations. A fifth group was formed encompassing the Far East members of the Program, increasing the efficiency in maintaining relationships with these firms. David A. Woodruff was appointed Director of Far East Corporate Relations, responsible for a staff of Industrial Liaison Officers in Cambridge and the MIT Japan Office in Tokyo.

Cynthia B. Bloomquist was named Associate Director of Corporate Relations, with special responsibility for relations with a group of key corporations not already members of the Industrial Liaison Program.

Thomas R. Moebus, formerly Associate Director of the Industrial Liaison Program, was promoted to Director of Corporate Programs with broad responsibility for managing efforts to develop corporate support for major academic initiatives, as well as significant responsibility in the management of the Industrial Liaison Program. David R. Lampe was named Assistant Director of Corporate Programs.

Frederick P. Gross, Director of Corporate Development, expanded his fundraising responsibilities and formed a group to undertake corporate research and stewardship. These responsibilities had been distributed in several areas of Resource Development. John S. Wilson was appointed as Assistant Director of Corporate Development.

Statistically, the year was also a good one. The Industrial Liaison Program closed the year with 279 members, generating \$8.5 million in revenues, compared with \$8.2 million the year before. Corporate gifts for the year totaled \$27.1 million, down 9% from the previous year. Total corporate commitments to the Campaign for the future stood at \$144 million at year end, 90% of the goal set for corporate gifts.

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The sudden death of Marie-Christine B. Greenberg, Marketing Assistant, was a great loss to the department and the Institute. The Marie-Christine B. Greenberg Scholarship Fund was established at MIT in her memory.

NATIONAL BUSINESS COMMITTEE

Robert Hagopian, Director, continued to develop new relations between MIT and corporations and government organizations. He also developed important relationships with alumni and friends and assisted other staff in this process. This included introducing newer staff members to volunteers and donors across the country, and coordinating National Campaign programs in Canada, Pittsburgh, and Seattle. He served as liaison for Resource Development's relationships with the Association of Alumni and Alumnae of MIT, including Visiting Committee and National Selection Committee nominations.

FOUNDATION RELATIONS

Barbara Gunderson Stowe, Director, intensified efforts to extend and strengthen the Institute's partnership with the foundation community. Particular emphasis was placed on inviting foundation officials to visit the Institute and on senior officer visits to major foundations. Major foundation grants were received to strengthen undergraduate science education, to support activities to promote the public understanding of technology and science, and to provide new opportunities for under-represented minority students.

CAMPAIGN SYSTEMS

Now in its second year of operation, the Office of Campaign Systems has kept pace with the research demands of the Campaign. The production of research reports is only one of several aspects to the information management support provided by Campaign Systems. Under the direction of Shelley Brown, the office continued to administer the Campaign's Prospect Management System and to develop and produce reports tracking prospect and staff activity and showing Campaign giving totals. This year new pledge tracking and reminder systems were added.

Programming support for the Campaign is the responsibility of Development Information Services (DIMS), managed by Gregory D. Whall. This year DIMS produced over 500 computer reports and developed an accounting system and an events tracking system. Both Shelley Brown and Gregory Whall, who chair the ADDS (database) Operations and Technical Groups respectively, have supported the efforts of the ADDS Efficiency Project undertaken with Administrative Systems Development, the Alumni Association, and the Treasurer's Office. These efforts, leading toward increased efficiency and decreased costs associated with the alumni/donor/development/schools database, have required considerable participation on the part of the DIMS staff.

Assistant Directors of Campaign Systems Lisa Peterson and Elizabeth A. Garvin both had responsibility for supervising a research team supporting the fundraising staff. Susan Cronin Ruderman, Manager of

Information Resources, administered Resource Development's research library and central file system. She also initiated a joint effort with the News Office and the Alumni Association in subscribing to a national newsclipping service.

Mary Gulino, Coordinator of Production Systems Support, provided Macintosh training and support to users. Assisted by Lisa Donovan, she was responsible for all mailings to volunteers and other key prospects and for the production of materials for Campus Visits and Campaign events.

There were several personnel changes this year. Elizabeth Garvin left to join the Alumni Association staff as Manager of Major Reunion Gift Committee Activities. She was succeeded by Nancy L. Olt. Susan Cronin Ruderman was promoted to the new position of Manager of Information Resources. Four promotions to administrative staff this year included: Charles R. Carr and Robert C. Arnold to Senior Research Analyst; Gail M. Masci and Stephen L. Gilligan to Programmer/Analyst I.

DEVELOPMENT SERVICES

At MIT, school-based fundraising has traditionally been project-driven rather than prospect-driven. Development Services responds to the needs of the five schools and the Office of the Provost for fundraising support services and liaison to the central Resource Development organization. Jack Oldham, the Director, chairs the monthly meetings of the school development officers and manages the research and support activities. The assistant directors work directly with the school development officers and the provost, providing prospect identification and research, proposal writing, project management, reports and stewardship plans as needed. This year the staff supported such fundraising priorities as the Leaders for Manufacturing Program, the Hazardous Substances Program, Minority Introduction To Engineering and Science (MITES), and the general drive for new professorships.

As the Campaign has progressed, the group's activities have shifted, now concentrating on increased support of cultivational events and solicitations, preparation of proposals and stewardship on professorship commitments. During FY89, the research staff responded to over 600 requests for information on potential donors; the professional staff wrote 35 proposals and arranged for over 70 stewardship reports to major donors, mostly regarding professorships.

Assistant Director Lisa Hiley supports the Office of Foundation Relations. She also assists Alfred Doig, the new Director of Development for the School of Engineering, with fundraising efforts within the School. She has provided a strong measure of continuity, coordinating MITES fundraising, stewardship reporting and proposal writing.

Assistant Director Mary Leen works closely with Ann Friedlaender, Dean of the School of Humanities and Social Science and David Lundberg, the new Director of Development. They have increasingly focused on individual prospects and the organization of cultivational events

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intended to generate interest in professorships, fellowships, scholarships, and faculty projects. They also continue to seek major support from individuals and foundations for curriculum innovation.

In the School of Architecture and Planning, Mary Leen and Assistant Dean Deborah Cohen have concentrated their efforts on raising funds for the renovation of Rotch Library. They have written several proposals seeking major grants for this project, and construction is currently underway. In addition, they have identified a select group of prospects for cultivation by Dean John deMonchaux for fellowships, professorships, and special programs such as lectures and an exhibition series.

The Office of the Provost, supported by Assistant Director John Jacoby, has developed several major initiatives now seeking funding. These include, "Project 2000," under the leadership of Dean for Undergraduate Education Margaret L. A. MacVicar, which provides donors with opportunities to name renovated classrooms. Dr. Jacoby has also been instrumental in coordinating reports to donors of endowed professorships and serves as liaison between the provost and the Campaign staff.

In the School of Science, Director of Development Judy Gooch has worked closely with Professor Mark Wrighton, head of the Chemistry Department, to solicit support for the department. A major project for the coming year will be funding a new program focusing on global change. Funding for the new Biology Building continues to be a priority, and the School is now approaching corporate donors for more broad support. Kay Tamaribuchi, Special Assistant to the Chairman of the Corporation, headed the staffing of these development efforts.

Nathaniel Mayes, Director of Development for the MIT Sloan School of Management, with the assistance of Alexandra Sabin, Assistant Director of Development for the School, is organizing corporate and individual fundraising, refining the school's needs and priorities lists and setting up prospect management and cultivation strategies.

Nancye Mims, following 3 years as Assistant Director, took a leave of absence in the fall in order to complete her legal studies.

COMMUNICATIONS

The Campaign continued to dominate the activities of the office. Particular attention was given to materials for training and supporting the volunteers. In the fall, a video, Volunteer Briefing, and a related guide were introduced to committees nationwide by the National Campaign staff. Throughout the year, the materials were used to conduct sessions on how to cultivate prospective donors and solicit sizable gifts of capital. A Corporation Development Committee newsletter, Campaign Reports, presented background information and a progress report to CDC members and other alumni volunteers working through Resource Development and the Alumni Fund. Spectrum, which covers news of the Campaign and profiles people and special programs at MIT, featured a number of prominent volunteers and donors. A series of "donor profiles," designed to inform alumni about planned giving options, was continued in Technology Review.

Fundraising brochures to be used by the volunteers as well as staff, faculty, and the administration included Dedication, a booklet recounting the satisfaction of 5 donors who have given named gifts to the Institute; Fellowships at MIT which makes the case for supporting graduate students; and booklets presenting information on the Cancer Center and the School of Architecture and Planning. The staff produced MIT Facts 1989, a 44-page booklet which presents a brief general overview of the Institute. In the spring, the office worked closely with the Dean for Student Affairs and new Parents Program staff to produce the first issue of a quarterly newsletter addressed to MIT parents.

Several publications addressed specific audiences. Japan and MIT is widely used in corporate relations with Japanese firms and Sustaining Fellows describes the goals and accomplishments of this generous donor group. A Recruiting Guide to MIT, a report based on a survey of corporate experiences at the Institute, is being used by the Industrial Liaison Program and other corporate fundraisers, as well as the Office of Career Development, to further enhance MIT-industry cooperation.

In the spring of this year, the office collaborated with the National Campaign Office to plan Event 128: A Salute to Founders. A 100-page book of founder profiles chronicled the success of 99 alumni and described some of the MIT experiences that nurtured this group's entrepreneurial skills.

Communications is responsible for Campaign publicity as it relates to events, gifts, and special projects. An intensive public relations effort for Event 128 generated substantial local and national press coverage. A news briefing for local papers and electronic media to release MIT: Growing businesses for the future, an analysis of the economic impact that MIT alumni have had on the Massachusetts economy, helped attract considerable press attention. Throughout the year the staff also worked on proposals to individuals and foundations and wrote Campaign-related letters and speeches for senior administrators and volunteers.

CORPORATION DEVELOPMENT COMMITTEE

The Corporation Development Committee (CDC) held its annual meeting at the Plaza Hotel in New York City on November 10, 1988. Chairman David Saxon presided. The program consisted of a morning meeting and lunch. The afternoon was devoted to a symposium entitled "Challenges to Financial Service Management" and a speech by Lester Thurow, Dean of the MIT Sloan School of Management, on "1989 with the New President." The Dalton Bowl was awarded at lunch to Carl M. Mueller '41. Attendees at both the CDC meeting and symposium totaled 107.

The CDC morning meeting heard a general overview of the Campaign presented by David S. Saxon, Chairman, and Glenn P. Strehle, Vice President and Treasurer. President Paul E. Gray spoke of the future of the Campaign. The MIT Productivity Commission's preliminary results were highlighted in a panel discussion by Provost John M. Deutch, Dean Lester C. Thurow, and Professor Michael L. Dertouzos, Director of the

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Laboratory for Computer Science. Volunteer issues were discussed by volunteer leaders Carl M. Mueller '41, Chairman, Corporation Campaign Committee; D. Reid Weedon '41, Chairman, National Campaign Committee; and Emily V. Wade '45, President, Alumni Association. James A. Levitan '45, Vice Chairman of the New York Campaign Committee, discussed the implications to charitable giving of the Alternative Minimum Tax. Then a panel consisting of D. Reid Weedon '41, John K. Castle '63, Norman B. Leventhal '38, Carl M. Mueller '41, and Stanley M. Proctor '43 analyzed from their respective points of view "Why Donors Give to MIT."

H. E. (George) Ramonat became Executive Director of the Corporation Development Committee, succeeding Joseph Collins, Managing Director of Alumni Activities. A new CDC working group assisted in the nomination process for new members and studied present and possible future roles for the Committee, and is managing the details for the meeting to be held on October 5, 1989.

GLENN P. STREHLE

ALUMNI ASSOCIATION

This was a year of yet another set of records. The Alumni Fund set new records in all of its categories with a record \$14.4 million and 29,132 donors. The Technology Day drew a recent year record of over 2,500 alumni and guests to the day or to reunions. We held our first fall class reunion and aided the Chemical Engineering Department in its centennial celebration. The Association also aided the *Campaign for the future* in the achievement of its stunning progress toward \$550 million of a year-end total of \$417.4 million.

The Association has operated for its first year in a new staff configuration designed to give us more alumni centered service. This reorganization also recognizes the flexible nature of alumni voluntary commitment to MIT. Our alumni, bless them, will do what MIT wants most. This new structure does away with the artifice of Fund versus Activities and recognizes the continuous nature of the relationship between voluntary time, commitment, cultivation, and financial support. Grouping our staff around the natural groupings of the audience, class, course, and geography enables us to bring more effective support to bear. You may note these changes did not have negative impact on success and may have had a very positive one. While all of the staff did a remarkable job, Joseph Collins (H), who took on the responsibilities for the management of the whole of Alumni Activities deserves special mention.

The Association benefited immensely this year by the thoughtful and caring leadership of its president Emily V. "Paddy" Wade '45. No one has given more of herself to the Association in my nine years Association CEO. The new Fund chairman, Richard Jacobs '56, had a most auspicious year. Key leadership this year came from a number of class leaders, including most notably, James Barton '39 and George Beesley '39. The Class of 1949 involved a broad committee, under the leadership of Thomas Toohy and James Christopher, which created a very successful reunion and an overachievement on their gift. Finally, special note should be made of the extraordinary success of the Alumni Fund Visit Program which has exceeded our most optimistic estimates. This effort involves many volunteers ably supported by a dedicated staff.

Two senior members of the staff left the Association this year. Webb Elkins SL'83 resigned to take a position in industry. John Mattill (H) retired as the editor of the *Technology Review* after 40 years of service to MIT--a truly exceptional time of service, commitment, and contribution.

The Association continues to thrive on the balanced combination of exceptional volunteers with a deep commitment, supported by a dedicated, creative, and hard working staff. This combination will enable our continued success.

ALUMNI ACTIVITIES

This year the Association underwent a major staff change in which the heretofore separate Relations and Fund staffs were merged into a unified Activities group consisting of five units. Individual reports are submitted below. The highlight of the year was the unprecedented success of the Alumni Fund, under the leadership of Richard A. Jacobs '56. The Fund reported gifts in the amount of \$14.4 million, a 16 percent increase over 1988, a new million dollar plateau, and a record sum. The number of alumni/ae contributors increased by one percent to 29,132, also a new record. The number and percentage of contributions at specific targeted levels of \$1,000 or greater, \$250 or greater, and \$100 or greater exceeded the year's goals and, for the first time, 40 percent of the alumni/ae donors gave at least \$100.

In terms of progress toward meeting the Alumni/ae Fund's goals within the *Campaign for the future*, the Fund has credited \$57 million toward its objective of \$100 million in cash receipts as of June 30. An additional \$12 million has been received in pledges.

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Alumni Visit Program

This program was established in FY88 as a major part of the Alumni Fund's role in the *Campaign for the future*. This year 129 volunteers in Boston, Cincinnati, Cleveland, Florida, Houston, New Hampshire, New York, New Jersey, S.E. Massachusetts, San Francisco, Silicon Valley, Los Angeles, and Washington, DC, called on 494 fellow alumni to seek five-year pledges of \$5,000 - \$1,347,808 was raised from 355 alumni, with an average gift increase of 94 percent.

Class Programs

Reunion programs and Technology Day 1989 in June attracted 2,500 alumni to MIT including representatives from the Classes of 1919 to 1989. The Technology Day 1989 program celebrated the 20th anniversary of man's walk on the moon and highlighted ongoing MIT space-related research activity. Professor Robert Seamans AA '42, Senior Lecturer, Department of Aeronautics and Astronautics, served as moderator and three of MIT's 17 astronauts were present for the program. Keynote speaker was Captain Richard Hauck NU '66, Commander of the Discovery Mission SIS-26. Other speakers included Claude Canizares, Professor of Physics; Edward Crawley '76 AA, Associate Professor of Aeronautics and Astronautics; Jack Kerrebrock, Associate Dean of Engineering and Professor of Aeronautics and Astronautics; Ronald Prinn CM '71, Professor of Meteorology ; August Witt, Professor of Materials Science and Engineering, and Lawrence Young '75 ME, Professor of Aeronautics and Astronautics.

The afternoon program featured a panel discussion on the *Commercialization of Space Technology*. Arthur Parthe ME '66, President of Parthe Associates and Executive Committee member of the Enterprise Forum, served as moderator, and presenters included Michael Beauchamp, Assistant Bank Examiner in the Treasury Department, Chicago; Byron Lichtenberg AA '79, Payload Specialist for ATLAS Spacelab Mission; David Mahoney, Vice President of Procurement of Sanders Associates; Beth Marcus CP '86, President and co-founder of EXDS, Inc; and Joseph Padavano '80 AA, Chief Engineer for Space Transportation Division of Orbital Sciences Corporation.

Fourteen classes celebrated reunions in activities which took place on campus, at sites in Boston and as far away as Bermuda. Special events included the traditional Thursday evening MIT Night at Pops, the annual Alumni Memorial Service in the MIT Chapel and the presentation of reunion class gifts at the Technology Day luncheon.

Gifts of the 25th, 40th and 50th reunion classes totaled nearly \$13 million. The 50th Reunion Class of 1939 made a precedent-setting gift of \$5.6 million from more than 80 percent of the class. This gift included \$389,000 in the Class of 1939 Scholarship Fund and \$79,000 in a fund for Materials Science. Also announced by the Class of 1939 was \$1,159,000 in future gifts to MIT. The 40th Reunion Class of 1949 announced a gift of \$5.3 million which included \$534,000 for the class scholarship fund. The 25th reunion gift of the Class of 1964 was \$1,964,000 with \$56,000 for student aid. Other reunion gifts announced were as follows: Class of 1984 5th reunion \$23,000; Class of 1979 10th reunion \$63,000; Class of 1974 15th reunion \$70,000; Class of 1929 60th reunion \$773,000; and Class of 1924 65th reunion \$2,054,000.

Graduate Program

The Graduate Alumni Program had a very successful year, raising \$2.5 million from 9,129 graduate alumni. These figures represent a five percent increase in donors and a 14 percent increase in dollars over FY88. Some 446 first-time gifts were received from those who graduated in the five most recent years. Eighteen department heads wrote solicitation letters to their graduate alumni. Sixteen graduate alumni telethons were held, including one co-sponsored by the Graduate Student Council to raise money for graduate student housing. The graduate alumni telethons brought in over \$286,000, more than twice the sum raised in FY88. In the publications arena, the Department of Earth, Atmospheric and Planetary Sciences department completed its first annual newsletter, while several other departments began plans for their first issues. Among numerous

course-related events, the celebration of the Centennial of the Department of Chemical Engineering drew 850 enthusiastic alumni and friends back to Cambridge in October. In March, all graduate students receiving degrees in 1988-89 were invited to attend the first annual series of graduate send-off dinners to congratulate them on their accomplishments and welcome them into the Alumni Association. The dinners, featuring keynote speakers Lester Thurow, George Hatsopoulos '49, Joan Goody, and Edward Lorenz MT '43, were attended by 416 people. A focus group was assembled to give guidance on programs for young Boston-area graduate alumni. The group's suggestions led to a survey of 2,500 young graduate alumni as well as quarterly newsletters and events for this constituency.

Parents Program

The Parents Program announced its presence to MIT parents in February with a letter from Alumni/ae Association President Emily "Paddy" V. Wade '45. A parents' reply form was enclosed to solicit information about family connections to MIT; the response was overwhelming. A sample issue of *Technology Review* and a survey of parents' interest in a "family weekend" were sent in April, again generating an excellent response. Subsequently, plans for a special weekend for parents and families were begun, with enthusiastic participation from students, MIT faculty, and parents.

Regional Programs

This year was highlighted by changes brought about by the reorganization of the Alumni Fund and Alumni Activities under the "Alumni Activities" rubric. The five Regional Directors are combining their skills with other staff program coordinators to promote young alumni, course oriented, and other activities targeted at other significant constituencies in their regions. For example, a very successful reception was held in Boston, especially for those alumni/ae who graduated within the last 10 years. In this way, we have looked at subsets of alumni/ae who have special cultivation needs and also reside within a certain geographic boundary.

Other regional programs of note were a theatre party sponsored by the New York Alumni Center hosted by MIT playwright Pete Gurney, a newly organized Enterprise Forum of Ontario co-sponsored by the MIT Club of Ontario and York University, and a reception at the Chicago Art Institute during its Gaugin exhibit. These are just a few samples of our very strong regional presence. Our 90 clubs worldwide meet as often as 30 times a year in our large urban centers and continue to evidence the vitality and commitment to MIT that is supported by a vast network of dedicated volunteers.

Regional telethons flourished as well with the annual Hartford event boasting 32 callers this year. Some of our other telethon cities were Atlanta, Houston, San Francisco, Chicago, and, of course, Boston.

Student Programs

Student Programs were running at full speed in FY89, preparing undergraduates to become engaged, committed alumni/ae of MIT, and harnessing their vast energies on behalf of the Alumni/ae Fund. The highlights of this year's programs were the Student Telethons, the Senior Dinners, and the Senior Gift/Pledge Program. The fall and spring Student Telethons engaged some 390 students in fundraising for MIT, and the results were outstanding; they contacted 7,289 alumni/ae and solicited \$266,086 in pledges from 4,616 donors. The Senior Dinners were equally successful, with 538 members of the Class of 1989 and 48 active alumni/ae joining Dr. and Mrs. Gray for dinner at the President's House. Finally, the Senior Gift/Pledge Program was the vehicle for their first gift to the Institute. Some 236 seniors contributed a total of \$5,674 to make up the Class of 1989 Gift, much of which was designated to the new "Class of 1989 Scholarship Fund." The class gift was supplemented by a generous challenge fund provided by the 50th Reunion Class of 1939. In addition, 166 seniors pledged a total of \$15,777 to the Alumni/ae Fund, payable over a four-year period.

616 Alumni Association

Telethon Program

Once again the Telethon Program proved itself an effective means of contacting large numbers of alumni. This year telethons were held on campus and in 16 cities throughout the country. A total of 865 student and alumni volunteers worked together to reach 16,300 alumni. Of those contacted, 72 percent made pledges totalling over \$884,000, breaking last year's record.

OTHER ALUMNI ASSOCIATION PROGRAMS

AMITA (Association of M.I.T. Alumnae)

The highlight of AMITA's program this year was the April 28 celebration of the 25th anniversary of McCormick Hall, MIT's first dormitory for women. The program, which included a brief history of the life of Katharine Dexter McCormick '04, donor of the funds for construction of the dorm, attracted over 100 MIT alumnae. Other AMITA activities for the year included publication of a quarterly newsletter, monthly meetings and the annual presentation of the AMITA Senior Woman Academic Award granted to Cynthia Wang '89.

BAMIT (Black Alumni/ae of M.I.T.)

BAMIT activities included the publication of a quarterly newsletter and an annual reception of graduating minority students. The BAMIT national meeting, held on October 21 and 22, 1988 included a testimonial dinner for retiring Associate Dean of the Graduate School, John B. Turner. In this year BAMIT has organized local groups of black alumni in the Washington, DC, and Philadelphia, PA, areas.

Boston Seminar Series

This popular lecture series attracted 235 subscribers this year for a program entitled, "Can We Afford A Balanced Budget or What's Next in An Age of Constraint?" Guest speakers included Dr. Ann Friedlaender '64, Dean, School of Humanities and Social Sciences, MIT; Dr. Roy Weinstein '51, Professor and Past Dean, College of Natural Sciences and Mathematics, University of Houston; Dr. Rashi Fein, Professor of the Economics of Medicine, Harvard Medical School; Dr. Alan Altschuler, Ruth and Frank Stanton Professor of Urban Policy, Planning and Design, Director of the Kennedy School State, Local, and Intergovernmental Center, Harvard University; Daniel J. Fink '48, President of D.J. Fink Associates, Inc., Chairman, NASA Advisory Council and Senior Consultant, Defense Science Board; Dr. Kenneth A. Smith '58, Associate Provost and Vice President for Research, MIT.

Young Alumni Program

Young alumni continued to demonstrate commitment and dedication to the Institute through their ongoing support of the Alumni Fund. Based on an expanded program this year, a record number of volunteers (101 in Fund Year 1989 versus 53 in Fund Year 1988) from the ten most recently graduated classes gave of their time to serve as Associate Agents or Reunion Gift Committee members, making calls from their homes to solicit gifts from their classmates. As a result of these calls, 406 donors, many of them first-time givers, gave \$19,269. This was an increase of 182 donors and \$8,271 over last year's home-based telethon solicitations. In addition, the Class of 1984, on the occasion of its fifth reunion, raised \$26,289 as its reunion gift--an excellent showing for a fifth reunion class. The Class of 1979 made an exceptional tenth reunion gift of \$71,543 with 51 percent of the class participating. Over \$29,000 of this amount was designated to the Class of 1979 Student Aid Fund, which now stands at \$115,660 and which has funded several young scholars.

With the continued buildup of staff support to execute the Alumni Fund's Campaign programs, combined with the effects of reorganization, this was a year of considerable change. Joseph S. Collins was appointed Managing Director, Alumni Activities while retaining his title as Director, MIT Alumni Fund. Mary K. Norman continues as Associate Director for the Alumni Fund Visit Program. Diana T. Strange continues as Associate Director with responsibility for the Classes and Events unit. Janet Serman was promoted to Associate

Director, Regional Activities, and is responsible for regional programs. Jeffrey R. Solof '81 was promoted to Associate Director, Alumni Activities, and heads up the Graduate, Parents, Students, and Young Alumni program areas. Joseph P. Recchio continues as Assistant Director responsible for Direct Mail, Donor Recognition, and coordination with the Association's computerized database group. Other promotions include Robert D. Blake and B. Frank Smith AR '68 to Senior Regional Directors, Mary B. Havlin and Bonnie S. Jones appointed as Regional Directors. In addition, Jodi E. Rafus was appointed Coordinator of the Direct Mail Program, following the resignation of June P. Coleman. New appointments include Elizabeth A. Garvin, Manager of Major Reunion Gift Committee Activities; Jane Grussing, Coordinator for Graduate Alumni Programs; and Marcia Hartley, Manager of Parents Programs.

In summary, the first year of reorganization went very smoothly and is a prologue to continued interface by the various staffs of the Association to better meet the goals of the organization.

Finally, it is most important to note the leadership provided by alumni volunteers, which sparks the programs supported by the Activities staff. The continuing success of the Alumni Fund and multitudinous other alumni programs is due primarily to the time, wisdom, and energy provided by thousands of alumni volunteers.

ALUMNI ASSOCIATION AWARDS:

Bronze Beaver Awards: S. Martin Billett, Class of 1948; Robert L. Mitchell, Class of 1947; William C. Rousseau, Class of 1936; Raymond S. Stata, Class of 1957.

The Harold E. Lobdell, Class of 1917 Distinguished Service Awards: David D. Adams, Class of 1950; Denis A. Bovin, Class of 1969; George F. Clifford, Class of 1948; Ernest R. Kaswell, Class of 1939; James N. Phinney (H); Russell S. Robinson, Class of 1932; Steven W. Swibel, Class of 1968; R. Gregory Turner, Class of 1974.

The George B. Morgan '20 Awards: Burton Angell, Class of 1943; A. William Avent, Class of 1942; Michael Biancardi, Class of 1940; Norman A. Chrisman, Jr., Class of 1949; Robert S. Gooch, Class of 1951.

The Henry B. Kane '24 Awards: Edgar P. Eaton, Jr., Class of 1944; Lewis H. Roosa, Class of 1949; Chenery Salmon, Class of 1926; Bennett M. Zarren, Class of 1961.

Presidential Citation Awards: MIT Class of 1939 for its 50th Reunion and Reunion Gift; Cleveland AFVP (Alumni Fund Visit Program); MIT Club of Dallas/Ft. Worth for excellence of service to alumni/ae in Dallas/Ft. Worth; MIT Club of Southwest Florida for sustained excellence in its service to alumni/ae and widows/widowers in Southwest Florida.

Honorary Membership in the Alumni Association: Norma Mele

The National Selection Committee made the following selections for terms starting July 1, 1989:

Elected to the M.I.T. Corporation: Karen W. Arenson '70, Peter M. Saint Germain '48, Raymond S. Stata '57.

Elected President of the Alumni Association: Harris Weinstein '56

Elected Vice Presidents of the Alumni Association: Robert L. Rorschach '43, R. Gary Schweikhardt GM '73.

Elected Directors of the Alumni Association: Philip R. Sayre '54; William B. Lenoir '61; Milton H. Roye '79; Walter S. Wojtczak '37; Samuel Denard '74; Antonia D. Schuman '58; Robert K. Bowden '70.

TECHNOLOGY REVIEW

Technology Review has accomplished several important goals this year. In the fall, we spent a great deal of thought and time, together with our Advisory Board and the Presidents Committee of the Board of Directors, fashioning a five-year plan, including editorial and financial objectives. In accordance with the plan, the editors began meeting weekly with distinguished members of the MIT community to enrich the magazine, increase the backlog of articles, and better reflect the kind of thinking that goes on at the Institute. We have taken major steps toward redesigning the national pages, which we felt was an important step in improving the commercial strength of the magazine. Other parts of the plan, including finishing the redesign and thoroughly re-examining the MIT section, remain for the coming year.

We have come in within our budget. Our expenses were within budget. Revenue falls into two parts: circulation and advertising. We did far better than projected on circulation. The January direct-mail campaign received the highest response in *Technology Review's* history. When promotion expenses are deducted from the subscription income, the campaign actually netted a small amount of income per subscriber in the first year. This is unusually good by industry standards. Unfortunately, advertising, which is sold for us primarily by the Leadership Network, netted less than expected. In accordance with our five-year plan, we have contracted with an advertising salesperson of our own and hope to do better in the coming year.

We won two major magazine awards: One was the John Bartlow Martin Award for Public Interest Magazine Journalism for "Radioactive Waste: Hidden Legacy of the Arms Race," by Robert Alvarez and Arjun Makhijani. Also, we won the Olive Branch Award for "The Stage Shifts in Arms Control" by Leon Sigal and Jack Mendelson. The MIT section of the magazine ran an in-depth series examining Project Athena that was well received by the community and the Project Athena staff. Examples of *Technology Review's* graphic design will appear in *Print Magazine's 1989 Design Annual*, a review of the nation's best design, photography, and illustration.

There has been a great deal of turnover in staff: Jonathan Schlefer, former managing editor, became the editor in chief; Sandra Hackman, former senior editor, became managing editor; and David Brittan, formerly of Issues in *Science and Technology* and *High Technology* was hired as associate editor. Beth Barovick, former circulation manager for MIT Press journals, became circulation manager, replacing Beth Rosner. Despite the turnover, the magazine has been coming out consistently on time and building a backlog of articles.

INFORMATION MANAGEMENT

The 1989 Alumni/ae Register was completed, and purchased copies were shipped all over the world. As a result of our rising computer costs a major overhaul is currently being done on the ADDS system. The expected completion date of the project is February, 1990.

ADMINISTRATIVE SERVICES

The administrative area spent a great deal of time organizing and correcting problems with the new Institute telephone system in 1988-89. There were a few small shifts in space assignments between Buildings #10 and W59, and work continues on refining the Alumni Association accounting and financial control systems.

With additional staff, we were able to provide better support in a number of areas and better information to the Alumni Association Board of Directors.

WILLIAM J. HECHT