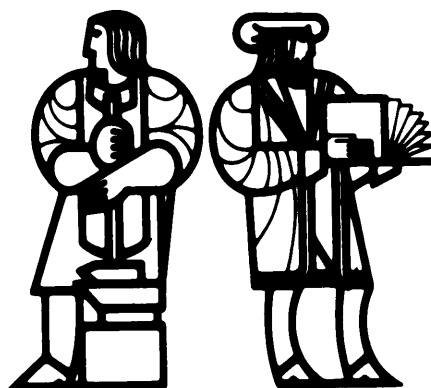

Massachusetts Institute of Technology

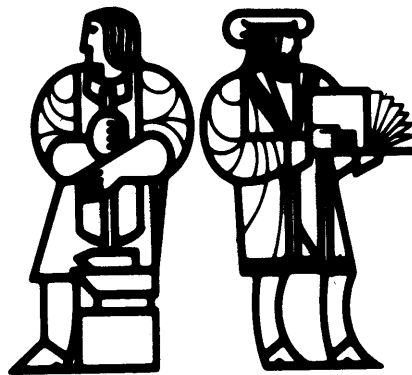
J. A. STRATTON
SEP 7 1989
Ref. to _____
File _____



Reports to the President

1987-88

Massachusetts Institute of Technology



Reports to the President

1987-88

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

The Corporation
1987-88

Honorary Chairman: Howard W. Johnson
Chairman: David S. Saxon
President: Paul E. Gray
Treasurer: Glenn P. Strehle
Secretary: Constantine B. Simonides

Life Members

George P. Gardner, Irénée du Pont, Jr., John C. Haas, Paul M. Cook, Ralph Landau, Carl M. Mueller, Breene M. Kerr, Louis W. Cabot, D. Reid Weedon, Jr., Jerome B. Wiesner, Kenneth H. Olsen, W. Gerald Austen, Howard W. Johnson, Ellmore C. Patterson, Edward O. Vetter, Frank T. Cary, Edward E. David, Jr., Norman B. Leventhal, Harold J. Muckley, John S. Reed, Jerry McAfee, Yaichi Ayukawa.

Members

Robert A. Charpie, Herbert H. Dow, W. H. Krome George, Floyd A. Lyon, Denman K. McNear, Rhonda E. Peck, Mary Frances Wagley, Donald J. Atwood, E. R. Kane, Margaret E. Mahoney, Robert L. Mitchell, Arlene F. Roane, Mitchell W. Spellman, Dolores Wharton, T. A. Wilson, Samuel W. Bodman, Joan T. Bok, Colby H. Chandler, Karen L. Fulbright, Michael M. Koerner, Christian J. Matthew, Robert J. Richardson, Robert A. Swanson, Emily V. Wade, E. Milton Bevington, Ernest U. Buckman, Alex W. Dreyfoos, Jr., Joe Farnham Moore, DuWayne J. Peterson, Jr., Charles H. Spaulding, Sarah A. L. Tabler, Morris Tanenbaum, E. Rudge Allen, John K. Castle, Robert B. Horton, Walter J. Humann, Shirley A. Jackson, F. Richard Meyer III, Rita A. O'Brien, Frank Press, Robin M. Wagner.

President of the Alumni Association

Raymond S. Stata

Representatives of the Commonwealth

Governor: His Excellency, Michael S. Dukakis
Chief Justice of the Supreme Judicial Court: The Honorable Edward F. Hennessey
Commissioner of Education: Harold Reynolds, Jr.

Life Members, Emeriti

Thomas D. Cabot, Crawford H. Greenewalt, William A. Coolidge, Robert C. Sprague, James H. Doolittle, Cecil H. Green, H. W. McCurdy, Robert C. Guinness, W. B. Murphy, Laurance S. Rockefeller, Julius A. Stratton, Luis A. Ferré, Semon E. Knudsen, Robert B. Semple, J. Kenneth Jamieson, Joseph J. Snyder, George W. Thorn, Frank R. Milliken, Gregory Smith, Richard L. Terrell, Kenneth J. Germeshausen

Contents

PRESIDENT	7
In Special Recognition	14
Statistics for the Year	19
Personnel Changes	22
PROVOST	42
Libraries	44
Lincoln Laboratory	50
Project Athena	55
Associate Provost and Vice President for Research	59
Francis Bitter National Magnet Laboratory	59
Center for Cognitive Science	62
Center for Materials Science and Engineering	65
Division of Comparative Medicine	68
Energy Laboratory	70
Harvard-MIT Division of Health Sciences and Technology	73
Mining and Mineral Resources Research Institute	75
Northeast Radio Observatory Corporation/Haystack Observatory	76
Nuclear Reactor Laboratory	78
Operations Research Center	83
Plasma Fusion Center	87
Research Laboratory of Electronics	95
Sea Grant College Program	100
Technology and Development Program	105
Technology Licensing Office	108
Whitaker College of Health Sciences, Technology, and Management	109
Department of Brain and Cognitive Sciences	111
Clinical Research Center	114
Associate Provost for Educational Programs and Policy	118
Office of the Dean for Undergraduate Education	118
Office of the Dean of the Graduate School	130
Lowell Institute School	148
Summer Session	149
Upward Bound Program	150
MIT/WHOI Joint Program in Oceanography and Oceanographic Engineering	152
Office of the Dean for Student Affairs	153
CHAIRMAN OF THE FACULTY	167
SCHOOL OF ARCHITECTURE AND PLANNING	172
Department of Architecture	176
Department of Urban Studies and Planning	180
Aga Khan Program for Islamic Architecture	183
Center for Advanced Visual Studies	186
Center for Real Estate Development	188
Laboratory of Architecture and Planning	190
Media Arts and Sciences Section	194
Media Laboratory	195

SCHOOL OF ENGINEERING	202
Department of Aeronautics and Astronautics	204
Department Chemical Engineering	207
Department of Civil Engineering	212
Department of Electrical Engineering and Computer Science	219
Department of Materials Science and Engineering	225
Department of Mechanical Engineering	234
Department of Nuclear Engineering	242
Department of Ocean Engineering	249
Artificial Intelligence Laboratory	255
Biotechnology Process Engineering Center	263
Center for Advanced Engineering Study	266
Center for Technology, Policy, and Industrial Development	268
Center for Transportation Studies	276
Laboratory for Computer Science	284
Laboratory for Electromagnetic and Electronic Systems	286
Laboratory for Information and Decision Systems	290
Laboratory for Manufacturing and Productivity	295
Leaders for Manufacturing Program	298
Materials Processing Center	300
SCHOOL OF HUMANITIES AND SOCIAL SCIENCE	302
Humanities, Arts, and Social Sciences Office	307
Department of Economics	309
Department of Humanities	312
Anthropology/Archaeology Program	312
Foreign Languages and Literatures Section	313
History Section	314
Literature Section	316
Music and Theater Arts Section	318
Writing Program	320
Department of Linguistics and Philosophy	321
Department of Political Science	323
Program in Science, Technology, and Society	325
Center for International Studies	327
Center for Materials Research in Archaeology and Ethnology	330
Integrated Studies Program	331
Statistics Center	332
Women's Studies	335
SLOAN SCHOOL OF MANAGEMENT	337
SCHOOL OF SCIENCE	357
Department of Biology	360
Department of Chemistry	362
Department of Earth, Atmospheric, and Planetary Sciences	366
Department of Mathematics	370
Department of Physics	373
Cell Culture Center	385
Center for Cancer Research	386
Center for Space Research	388
Experimental Study Group	393
George Russell Harrison Spectroscopy Laboratory	395
Laboratory for Nuclear Science	400
Bates Linear Accelerator	408
George R. Wallace Astrophysical Observatory	410

VICE PRESIDENT, EQUAL OPPORTUNITY OFFICER, AND SECRETARY OF THE CORPORATION	411
Office of Admissions	414
Educational Council	416
Department of Athletics	417
Career Services and Preprofessional Advising	426
Medical Department	428
MIT Press	433
Personnel Office	438
Public Relations Services	443
Quarter Century Club	448
Secondary Technical Education Project	449
Office of the Secretary of the Corporation	450
Council for the Arts	456
List Visual Arts Center	459
VICE PRESIDENT FOR FINANCIAL OPERATIONS	463
Office of the Comptroller	466
Office of the Director of Finance	469
Office of Purchasing and Stores	471
Office of Registration and Student Financial Services	473
Office of Sponsored Programs	486
VICE PRESIDENT FOR INFORMATION SYSTEMS	490
SENIOR VICE PRESIDENT	497
Campus Activities Complex	498
Campus Police	499
Endicott House	500
Graphic Arts and Audio Visual Services	501
Housing and Food Services	502
Office of Facilities Management Systems	503
Physical Plant Department	504
Planning Office	506
Safety Office	508
VICE PRESIDENT AND TREASURER	509
ALUMNI ASSOCIATION	517

PRESIDENT

There are moments in the life of a university that remind us that behind all the academic programs, the organization, the press of activity, there is a vision. This past winter, MIT lost one of the major figures in its history — James R. Killian, Jr., former President and Chairman of the Corporation. As tenth president, Jim Killian embodied and articulated the best of MIT, and kept before us the vision of why this university is so special, so right for its times.

The Corporation of MIT, at its meeting in March, adopted a set of memorial resolutions that captured the significance of this man and his time in MIT's history:

Those of us who knew him and worked with him have lost a warm and wise friend whose life we were fortunate to share. Through more than half a century of exemplary dedication to MIT, Jim Killian demonstrated rare qualities of mind and spirit. In the most critical times his perspective was invaluable in understanding and strengthening the role of technology in modern society. He initiated the postwar evolution of MIT to what he called a "university polarized around science, engineering, and the arts," a vision that gave a humanistic sensitivity to its role as a foremost institution of science and technology.

Throughout an association spanning more than sixty years, Dr. Killian's contributions to MIT were enormous. His deep understanding of its goals and his wise judgment have left a mark upon the Institute that will never be forgotten. A man of enviable erudition, Jim Killian possessed as well a natural eloquence and charm, a warm and gracious manner, and a gentle, wry humor that was never unkind. All these gifts he put to use in the service of MIT. . . .

Dr. Killian's commitment to public service was equally impressive. During the 1950s he served President Eisenhower in evaluating national technological and intelligence capabilities, and, as Presidential Science Adviser from 1957 to 1959, Dr. Killian put into place a strong mechanism for providing U.S. presidents with the best scientific advice the nation had to offer. Although he was not a scientist himself, Jim Killian always had a rare and special understanding of what it means to be a scientist, and it was because of this valuable insight that he was such a great leader of scientists. . . .

The consummate servant of the public interest, he possessed a foresight and vision that brought into being official national concern for arms control and disarmament, and launched and nurtured the public broadcasting system in this country.

He once described the central challenge facing American universities as "the imperative to be relentlessly first rate, to maintain such high credibility, creativity, and luminous excellence that they enlarge the national vision and enhance the national confidence." This statement of the challenge to universities — to this university — applies with equal force and reason today, as we face the upcoming national elections and a new century that is little more than a decade away.

What role should the universities play in the national agenda, and how do science and technology, as well as basic research and education, fit into that agenda as it will be framed by the next President of the United States?

We live in a complex and even paradoxical world, a world in which security and plenty for some sets in relief a world beset by hunger, disease, pollution, and poverty for many, a world riven by political and racial discord, a world still threatened by nuclear arms. It is vital that our young scientists and engineers — and social scientists, architects, and managers — be educated to meet the challenges of our world and our time. They must be prepared to address issues that are central to the preservation and enhancement of life and to consider critical questions about the interplay between science and technology and the social, cultural, environmental, and economic settings in which new scientific knowledge and technological applications are pursued.

MIT, Education, and the National Agenda

I do not pretend that we have all the answers or that MIT has a corner on wisdom in this domain, but we are taking a searching look at what we teach, whom we teach, and how we teach — particularly at the undergraduate level. I believe the kinds of questions we are asking, the kinds of challenges we are posing for ourselves, bear directly on the national agenda — if that agenda is to include such goals as health, prosperity, and security, not just for this nation, but for this planet.

That sounds ambitious, even presumptuous, but we are privileged to be in a special position to address these challenges. We have as our students some of the brightest young people our nation and the world have to offer. We have as our faculty a premier assembly of scholars. And we have as our mission a tradition, a legacy, of identifying and serving the needs of the society. This mission has guided the evolution of MIT with a sureness and steadiness of purpose that is one of our greatest strengths.

As I have noted in the past, the culture of this place, and the kind of overall educational experience that students have here, depend greatly on the interests and backgrounds of the students themselves — the culture they bring with them and the culture they create while they are here. In recent years, we have paid closer attention to the influence of our students on our educational program — recognizing that a broader range of primary intellectual commitments and social and racial backgrounds is central to our goal of encouraging our students to value different perspectives and points of view, and to recognize and be able to deal with the social, political, and economic complexities and contexts of scientific and technical enterprise.

We have achieved some success on this front. The class entering in the fall of 1987, for example, was very strong academically, exhibiting broad intellectual interests, wide cultural diversity, and a better racial balance than any previous class. We are beginning to see this increased plurality of perspectives and interests reflected in students' choices of major, a development that should underscore our efforts to develop an educational program that is better able to identify and integrate different perspectives and approaches to learning.

In my recent annual reports, I have discussed some of the ways in which the faculty has been reviewing the academic program in order to prepare our students for the kind of professional and social responsibility we deem to be appropriate for our times. We have made progress in the last year:

- We have implemented those changes affecting the General Institute Requirements in the Humanities, Arts, and Social Sciences that were adopted by the faculty late in the spring of 1987. These changes — designed to provide greater focus and rationale for the study of these fields in the core curriculum — reduce the fragmentation of distribution subjects and group them into five thematic areas of study: literary and textual studies; language, thought, and values; the arts; cultures and societies; and historical studies. This reformulation, which formally incorporates the arts for the first time, should provide greater depth and focus to this important part of every student's program.

- The faculty Committee on the Undergraduate Program has begun a thorough review of the General Institute Requirements in mathematics and science. In our core program, we have tried to balance concerns for general education with the need for preparatory studies in basic sciences as a foundation for departmental requirements. This balancing act has led to a certain rigidity in the science core, however, and it is time to take a new look. In particular, at a time of great intellectual and practical strides in the life sciences— an area where MIT offers unsurpassed leadership and achievement — our undergraduates are currently not required to include such study in their programs. The Committee is exploring both the appropriateness of such a requirement and how it would be accommodated within the structure of the Institute Requirements. In addition, the content and style of the core physics, calculus, and chemistry subjects are being examined with an eye to reinforcing and extending the basic concepts that bridge across these subjects. In addition, one of the most passionately discussed issues is the widely felt need for additional, hands-on laboratory experiences for our undergraduates, especially at the introductory level. This review will be completed, and a recommendation will be made to the faculty, in the coming year.
- The Committee has moved beyond the formal curriculum to review several aspects of the undergraduate program that affect the style and character of education at MIT. These include: grading policy — with particular emphasis on the first-year system of pass/no credit grades that has been used for the past twenty years; the structure of the first-year program, particularly the question of the content, sequence, and timing of the core science subjects; calendar and scheduling matters, including the question of the role and character of the January Independent Activities Period; and community expectations and attitudes which affect the intensity and pace of study at the Institute. These features of our program, taken together, create an environment that signals to our students the nature of the learning we expect from them, and thus deserve serious consideration.
- During the past two years we have given considerable attention to the academic advising of first-year students. One of the outcomes has been the development of personalized advising seminars, in which small groups of first-year students meet regularly with a member of the faculty who is responsible for both the content and conduct of the seminar and for the advising of the students in it. Starting from six pilot seminars two years ago, there were twenty-five such seminars this past year. In the coming year there will be about sixty, involving six hundred students, or 60 percent of the incoming class. Had we planned more seminars, we could have accommodated another 125 students who requested them. Clearly, this effort is a success.

These are but headlines about some of the explorations taking place throughout the Institute, as we seek to ensure that our educational program continues to prepare our students for full, responsible professional, social, and personal lives.

One of the most exciting such activities has come from two interschool faculty working groups that have had faculty from different fields coming together to examine the nature and conduct of undergraduate education at the Institute and, specifically, to develop new subjects and academic experiences that will directly address the relations of science, technology, and society.

I referred in my report last year to the initial stages of this effort to develop a set of “context courses” that would be taught on an interdisciplinary basis by two or more faculty from different schools. A great deal of progress has been made on this front in the past year, as faculty have developed an initial set of subjects ranging over a broad spectrum of issues, but all having a set of common objectives:

- to make students more conscious of the significant commonalities that link the study of science and engineering with other branches of knowledge and to become more skillful at making such connections themselves;

- to increase understanding of non-scientific and non-technological aspects of work in science and engineering — such as the political, economic, and managerial considerations integral to scientific and technological projects, or the social consequences of certain directions of scientific research;
- to encourage students to be more reflective about the social implications of individual actions and to motivate discussion of such issues as balancing the demands of personal and professional life.

This coming year, nine pilot subjects are being offered:

Automation, Robotics, and Unemployment
 AIDS: Scientific Challenge and Human Challenge
 Life and Institutions of Science
 Does Technology Drive Politics?: The Decision to Build the H-Bomb
 Negotiation in Engineering Systems
 Engineers, Scientists, and Public Controversies
 Accounting for the Social Consequences of Technological Change
 Industrial Competition in the US and Asia
 Learning to Design and Design for Learning

We hope that these subjects, and others still being developed, will provide students with a better understanding of how scientists and engineers go about doing what they do; how they work differently from each other, and from artists and humanists; and how the different perspectives of these various disciplines need to inform the identification and resolution of some of the most critical issues of our times.

We are just in the initial experimental phase of this program; nevertheless, I am hopeful that this type of intellectual experience may eventually become an integral part of our degree requirements. In any case, the goals and the theme of this effort reflect the essential spirit of what we are trying to do in reviewing our educational program: to enable students to understand and to integrate into their learning and work the concept of science and technology as enterprises that have enormous influence on society, and that are — in turn — shaped by social, economic, and political forces.

Educational renewal is no easy task. There will always be legitimate questions raised when we set about to improve on a good thing. Such questions are natural, they are important, and they are welcome.

In the coming year, for example, the faculty Committee on Undergraduate Admissions and Financial Aid will be looking at the nature and success of the recently admitted classes. If, and it is a big *if*, there are some real differences in performance between the more recent classes and their predecessors, we must ask ourselves to what extent such differences are due to changes in selection criteria, to what extent they are related to the general state of science education in the primary and secondary schools, and to what extent we want to accommodate our curriculum to our students, and vice versa.

In the culture of MIT, changes that address the larger issues and goals in education must be done with the leadership and participation of the faculty. While there is general recognition that these larger issues are important and should have a place in our educational program, there is often little agreement about what should be done, or how. It is clear to me, however, that we must work together to reach common understandings and consensus on these matters, and that this way of doing things takes time and talking and trying things out. Sometimes it seems enormously difficult to engage the fundamental issues with many small steps rather than giant leaps forward, but if these innovations are to become part of the culture of this place, they must be consonant with this culture.

I believe this past year has been one of progress in an enterprise that is continually evolving to meet our own highest standards. There is no question in my mind that the kind of education we provide and the kind of students we teach will continue to play an important role in our national agenda — both in framing the important issues, and in helping our citizens and leaders to understand and participate intelligently in the development and appraisal of public policy on scientific and technological issues that bear on the well-being of our society.

Role of Science in Public Policy and a Democratic Society

Just as it is important for science-based universities to place science and technology in the broader social context — to recognize and discuss explicitly the social, political, and economic implications of science and engineering, so it is important for the more general society to incorporate a better understanding and appreciation of science and technology as practical, powerful realities in our lives.

We live in an age in which science and its technological fruits are growing in significance and influence. Few would argue with the thesis that our society, our culture, our lives have come to be increasingly dependent on technical knowledge. And yet there is widespread and increasing scientific illiteracy — even hostility to things scientific — within the general population. At the same time that there are ignorance and fear of science and technology, there are extraordinary expectations that scientists and engineers — the experts — will overcome intractable problems literally on demand, problems such as AIDS, massive hunger, or global environmental pollution.

These fundamental problems affecting all of our lives — public health issues, international security, energy, and the environment — contain major scientific and technical components, to be sure, but we make a grave mistake in this nation if we assume that the responsibility for dealing with such issues rests with the experts, with our graduates and others similarly prepared. We are a nation at risk if we continue as we have been with a public unable to distinguish sense from nonsense in the domain of science and its applications, and with an electorate unable to comprehend the arguments arising at the intersection of science, technology, and public policy.

And that is, I submit, a major challenge for our national leaders: how should science and technology — in education and research — fit into this nation's agenda? I believe it is time, it is past time, that high priority be given to support of the sciences and technology, particularly in the education of the general public.

Scientific literacy does not mean expertise. It means the capacity to reason in quantitative terms. It means familiarity with a basic scientific vocabulary and fundamental concepts about physical and biological processes. In sum, it means a reasonable intuition that is informed by the principles of science.

Let me give just one major example of such a public policy issue that requires a much greater level of understanding and cooperation among individuals and institutions if we are to come to grips with it. This past summer, as farmlands dried up throughout the midwest, and the temperature reached record highs throughout the land, the country awakened to the fact that something may be very wrong with our climate. The "greenhouse effect" was on everyone's lips. While it is not certain that the weather in the summer of '88 is a consequence of global warming associated with increasing concentrations of carbon dioxide and other greenhouse gases in the atmosphere, one thing is certain. If the present rate at which greenhouse gases are being produced is not sharply curtailed, the earth will soon be warmer than it has been in 100,000 years; by the end of the 21st century it is likely to be warmer than it has been in at least two million years.

As a result of such warming, sea levels will rise dramatically, resulting in erosion of beaches and destruction of seacoast property, and changes in climate and weather patterns are likely to have major consequences for agricultural economies, for ecological systems, for all living things.

We may not know the details or be able to predict all the consequences of this global warming, but we *can* say already that efforts to slow further warming and to adapt to these temperature increases will stress the political systems of the world, will require massive changes in patterns of energy use and in energy sources, and will affect the lives of all inhabitants of the earth. The public policy issues which will arise — the choices to be made — require a much better public understanding of both the underlying science and the impact of a variety of technological matters.

Without such understanding, decisions will be made by those who have the greatest access to scientific and technical understanding and resources. These matters are too important, too permanent, to be made without broad understanding and consensus. Indeed, without such understanding and consensus, no effective action is possible.

Science and Technology and the National Agenda

There are several ways in which science and technology should find a more prominent place on the national agenda:

- First, there must be renewed support for the education of scientists and engineers. During the past twenty years, the number of students pursuing graduate studies to the doctoral level has not increased to meet the needs of the nation, and many universities find it increasingly difficult to fill faculty positions.. The costs (in time and money) of pursuing a doctoral degree give pause to those who — with a master's or even a bachelor's degree — can find fulfilling, rewarding careers in business, government, and industry. At the same time, foreign citizens make up a growing percentage of graduate enrollments. At present, nearly half of the recipients of doctoral degrees in science and engineering are foreign citizens. Many of these individuals are required by our immigration laws to leave the United States upon completion of their studies, despite their own wishes to remain in this country. Consequently, they are unable to contribute to the needs for researchers and university faculty here — needs that are now increasing considerably as the generation of men and women who made possible the post-war expansion of the U.S. educational and research systems approaches retirement.

The nation responded to a similar need thirty years ago by creating fellowship programs to support graduate students. Similar programs today could have major effects without straining our already overburdened Federal budget; programs that would support two thousand graduate students per year (a significant addition to the present doctoral enrollments in science and engineering) could be funded at an annual cost of about \$40 million.

- At the same time, modest increases in support of university-based research programs and facilities are necessary and entirely consistent with expansion of graduate enrollments. These needs have been explicated repeatedly over the past decade, and I will not reiterate those arguments here. Suffice it to say that expanded support at the levels required could be achieved by reallocation of the present commitment of Federal funds to research and development. Of the present commitment of nearly \$60 billion, only about \$8 billion is devoted to university-based research. The leverage for the nation, in terms of expanded education, an invigorated flow of new knowledge and innovative ideas, and a more adequate production of researchers, would be great.
- Improvements in the general level of scientific literacy and mathematical competence require much greater attention to and emphasis on the importance of these subjects in the public schools. We need better-prepared teachers and new approaches to the teaching of science — approaches which emphasize the process and intellectual excitement of science, rather than the rote learning of facts, which engage young people in the process of learning by doing, and which emphasize the cultural and intellectual unity of science and human values. The primary responsibility for this aspect of U.S. education rests with tens of thousands of local schools and school boards. But national leadership — particularly presidential leadership — could make a tremendous difference.

- Finally, our attention to education in science, mathematics, and engineering at all levels — indeed, our attention to education generally — must reflect the fact that the population of young people of school age in the U.S. is now changing dramatically. Black and Hispanic children will be a much larger fraction of the age cohort by the turn of the century than they have been in the recent past, and they will comprise a much larger fraction of the work force in the 21st century than has been the case. Historically, these segments of the American population have been underrepresented at MIT and in science and engineering careers generally. We have worked hard on correcting this underrepresentation at MIT for two decades, and we will continue to do so. But there must be stronger national efforts to increase the proportion of minorities who study and pursue careers based on science, mathematics, and engineering.

The integration of science and technology into the mainstream of American education and priorities is not a self-serving goal. An educated citizenry — literate in science and technology — is vital to the well-being of our society and to the preservation of our democratic system of governance.

This is a challenge for our national leaders. And it is a challenge for MIT. Thirty years ago, at a time that was in some ways not so different from today, Jim Killian summed it up this way:

... it is our continuing responsibility and opportunity at MIT to express with poise and composure the beneficent values of science and all other forms of creative intelligence and to combat the anti-intellectualism which deprecates these values. We have an unusually urgent responsibility now to stress the true character of science as a liberalizing, humanizing and creative force that serves man spiritually as well as intellectually and practically.

Our ability to fulfill this responsibility is dependent on our greatest resource: the extraordinary quality of our faculty and students. Assuring their strength and productivity takes resources of another kind, financial resources. Last fall, we undertook the most ambitious fundraising campaign in MIT's history, the *Campaign for the future*, with a goal of raising \$550 million dollars by June of 1992. The primary focus of this campaign is endowment — for faculty support, for financial aid, and for new educational initiatives and research programs. We are succeeding. When we closed the books at the end of June, we had raised just over \$314 million in gifts and pledges — an extraordinary vote of confidence from our alumni and friends, and a great tribute to all of the volunteers and staff who are dedicating themselves to this tremendous enterprise.

I do not pretend for a minute that the goals of the campaign are the end. They are the means to the end: an MIT that continues to have the confidence, the ability, and the will to chart new horizons and to educate students who will help shape the course of science, technology, and society. In the final analysis, as Jim Killian said, "The wealth of an institution is not measured by money, but by its character, its excellence, its human resources, and its service."

PAUL E. GRAY
September 1988

In Special Recognition

This past year witnessed many occasions for special recognition of achievements by MIT faculty, students, and staff. Not only did we recognize our own, but it was also a year when the world took note.

This spring there was international acclaim for the successful flight of MIT's ultralight human-powered aircraft, *Daedalus*, over the Aegean Sea from Crete to the island of Santorini. The plane was designed and constructed by MIT students, faculty, and alumni to recreate the mythical flight of the Greek engineer and architect for whom it was named. Powered and piloted by Greek cycling champion Kanellos Kanellopoulos the 69-pound craft — flying 25 to 30 feet above the water — completed a flight of nearly 73 miles in just under four hours. This flight more than tripled the world's distance record for human-powered flight and established a new endurance record as well. It was an astonishing physiological and engineering feat, built on the dreams and dedication of the MIT team, headed by project manager John S. Langford, and supported by the generosity of several corporate sponsors and the Government of Greece.

Two members of the MIT faculty were recipients of the Nobel Prize this year — Institute Professor Robert M. Solow, Department of Economics, was the recipient of the 1987 Nobel Prize in Economic Science, and Professor Susumu Tonegawa of the Department of Biology and the Center for Cancer Research won the 1987 Nobel Prize in Physiology or Medicine.

The Royal Swedish Academy in Stockholm, which administers the Nobel prizes, cited Professor Solow for his pioneering contributions to the theory of economic growth, work that goes back some 30 years to the mid-1950s. The selection committee cited his development of a mathematical model showing that long-term growth depends on technological progress, and is not driven only by increases in capital and labor. "Solow's model had an enormous impact on economic analysis," the Academy's citation said, adding that the model amounted to a "framework within which modern macroeconomic theory can be structured."

Professor Tonegawa was awarded the prize for his work that revolutionized the understanding of the human immune system. Dr. Tonegawa's work unraveled a major biological mystery: how the limited genetic complement of an animal can produce the immense diversity of antibodies that attack bacteria, viruses, and toxins. As Dr. Tonegawa explained, "Genes coding for antibodies can change during the lifetime of an individual. The problem of how our body can respond to so many different kinds of pathogens was one of the most hotly debated issues in immunology. We did not understand how that happens. It turned out, contrary to what many people thought, that in the immune system genes can change during the life cycle of an individual."

In addition, Professor Tonegawa was named corecipient of the 1987 Albert Lasker Medical Research Award, considered by the medical community in the United States to be second only to the Nobel Prize in importance. He shared the 1987 award with Dr. Philip Leder at Harvard Medical School and Dr. Leroy Hood at the California Institute of Technology. The award cited the three researchers for their independent work in explaining the immense diversity of antibodies produced by the body which participate in the attack on foreign agents such as viruses and toxins.

Three members of the MIT faculty were elected members of the National Academy of Sciences. Those new MIT members are: Maurice C. Fox, Professor of Molecular Biology, Ann M. Graybiel, Professor of Neuroanatomy, and Morris Halle, Institute Professor and Professor of Linguistics.

In the spring the National Academy of Engineering elected five members of the MIT faculty to membership. New MIT members are: Barbara H. Liskov, NEC Professor of Software Science and Technology, Department of Electrical Engineering and Computer Science; Sanjoy K. Mitter, Professor of Electrical Engineering and Computer Science and Co-Director of the Laboratory for Information and Decision Systems; Ronald R. Parker, Professor of Electrical Engineering and Computer Science and Director of the Plasma Fusion Center; Theodore H. Pian, Professor of Aeronautics and Astronautics; and Neil E. Todreas, Professor of Nuclear Engineering and Head of the Department of Nuclear Engineering.

Six members of the MIT faculty were elected fellows of the American Academy of Arts and Sciences. They are: Richard P. Stanley, Professor of Applied Mathematics; Mark S. Wrighton, Frederick G. Keyes Professor of Chemistry and Head of the Department of Chemistry; Sheila E. Widnall, Abby Rockefeller Mauzé Professor of Aeronautics and Astronautics; Oliver D. Hart, Professor of Economics; and Heather N. Lechtman, Professor of Archaeology and Ancient Technology and Director of the Center for Materials Research in Archaeology and Ethnology.

Professor Morris Cohen, Institute Professor Emeritus and renowned metallurgical scientist, was chosen to receive the Kyoto Prize in Advanced Technology. Professor Cohen was awarded the prize in November 1987 in Kyoto, Japan. Dr. Cohen has made major contributions to the understanding of the structure of matter and the ways in which various materials, particularly iron and steel, can be processed to provide controlled structures and improved properties.

In June 1988 it was learned that the Inamori Foundation of Japan selected Noam A. Chomsky, Institute Professor and Professor of Linguistics, to receive one of the 1988 Kyoto Prizes. Three Kyoto Prizes are awarded each year — in Advanced Technology, Basic Sciences, and Creative Arts and Moral Sciences. Professor Chomsky won the prize in the basic sciences for his theories on the nature of language that have revolutionized linguistic science.

In the spring the President of the Italian Republic, Francesco Cossiga, presented the 1988 De Gasperi Prize in science, the highest award given by the Italian Republic, to MIT Professor of Physics Samuel C. C. Ting. This marked the first time that the De Gasperi Prize in science was awarded to a non-Italian. Dr. Ting was cited for his contributions to "the progress of science in one of the most advanced sectors of peaceful research. . . . [and] also because of his involvement in promoting international scientific collaboration for a science without secrets and without frontiers, through his active participation in establishing the World Lab and in realizing his programs of scientific and technological collaboration, east-west-north-south."

Dr. Sheila E. Widnall, Abby Rockefeller Mauzé Professor of Aeronautics and Astronautics, received the prestigious Bradford Washburn Award from the Boston Museum of Science in the fall of 1987. The award is given annually to a person who has made "an outstanding contribution toward public understanding of science, and appreciation of its fascination and the vital role it plays in our lives." Professor Widnall was particularly cited for the role she has played as president of the American Association for the Advancement of Science in guiding that organization which influences sciences policy for the country.

Within the Institute, John S. Waugh, Professor of Chemistry, was selected as the 1988-89 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 committee's citation said in part: "Recognized widely as an authority on physical chemistry, John has contributed to the intellectual life of the Massachusetts Institute of Technology in many respects. His fine mentorship qualities have enriched his many students, postdoctoral associates, and faculty colleagues. He has been a role model for junior faculty and faculty at other leading academic institutions. John's infectious enthusiasm for quality science has spawned one of the finest physical chemistry programs in the world."

In the late spring, Peter C. Perdue, Associate Professor of History, was named the 1988 recipient of the Harold E. Edgerton Faculty Achievement Award. The award is given annually to a junior faculty member who has made outstanding contributions in research, teaching, and service to the MIT community. The selection committee noted in its citation: "Peter Perdue is distinguished, in short, by his contributions and achievements as a contemporary historian of China, by his vocation for teaching and the range of his contributions to MIT's educational program, and by his willingness and ability to work innovatively on projects that demand collaboration with people in other departments and schools."

In April, MIT honored former president and chairman Howard W. Johnson for "two decades of brilliant and caring leadership" in naming the Athletics Center for him and announcing both the establishment of the Howard W. Johnson Professorship of Management and the creation of a Sloan School lecture series in his name. The official resolution of the MIT Corporation naming the Athletics Center for him praised Howard Johnson as "a man of uncommon vision and dedication, whose clarity, wit, and wisdom have added over many years to the stature of MIT. . . ."

* * *

This past year several key leadership roles at the Institute changed, and those transitions were occasion for special recognition.

New department or program heads announced during the past year are: Robert J. Birgeneau, Head, Physics; Richard M. Douglas, Head, History Section, Department of Humanities; David M. Epstein, Head, Music and Theatre Arts Section, Department of Humanities; Thomas H. Jordan, Head, Department of Earth, Atmospheric and Planetary Sciences; J. David Litster, Director, Francis Bitter National Magnet Laboratory; Earll M. Murman, Director, Project Athena (effective September 1988); Ronald R. Parker, Director, Plasma Fusion Center; William L. Porter, Head, Department of Architecture; and Bernhardt J. Wuensch, Director, Center for Materials Science and Engineering.

Major changes in the Institute's central administration during the year included the appointment or promotion of the following individuals: Donna M. Behmer, Assistant Dean for Administration at the Sloan School of Management; H. Eugene Brammer, Associate Director for Operations of Physical Plant; Anne P. Glavin, Chief of the MIT Campus Police;

Lawrence E. Maguire, Director of Housing and Food Services; Kathryn W. Lombardi, Director of Public Relations Services and Executive Assistant to the President; Travis R. Merritt, Associate Dean for Student Affairs.

* * *

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

As I noted at the beginning of this report, the Institute this year marked the passing of James R. Killian, Jr., former president and chairman of MIT, the first science advisor at the White House and a key figure in developing American educational and scientific policy during the mid-20th century. Dr. Killian died in January 1988 at the age of 83. For some 60 years Dr. Killian's life was intimately involved in the development of MIT as one of the leading scientific universities in the world. He served as president of MIT from 1949 to 1959 and then as chairman of the Corporation until 1971, a 22-year period marked by great expansion and building, by increases in graduate study and in research, and by expansion of the humanities and social sciences. Dr. Killian was a leading spokesman for educational innovation and curriculum reform; for the strengthening and

broadening of engineering education; and for greater support of basic research. As Special Assistant for Science and Technology to President Dwight D. Eisenhower, he played a key role in laying the groundwork for what became the National Aeronautics and Space Administration — NASA — and guided it, as President Eisenhower wanted, toward civilian rather than military control. Dr. Killian also was a leader in establishing public television and public radio, wherein he saw a new technology in the public interest. He was a man of vision, grace, wit and wisdom who devoted the full measure of his extraordinary energies and skills to MIT. It was always our good fortune that Jim Killian cast his lot with us — we are all the better for having known him.

Walter J. Beadle, life member emeritus of the Corporation and the Corporation's most senior member, died in February 1988. A member of the Class of 1917, he interrupted his studies to serve in World War I and received his SB degree in 1920. He joined E. I. duPont de Nemours Co. in 1928, retiring from the company in 1958 and from its Board of Directors in 1975.

In May 1988 Russel DeYoung, former chairman of the Goodyear Tire and Rubber Company, died at the age of 79. Mr. DeYoung was a life member emeritus of the MIT Corporation and a graduate of the Sloan Fellows Program. He served with the Goodyear Tire and Rubber Company from 1927 until his retirement in 1974, after which he continued to serve as director and chairman of the board's executive and finance committee until 1979.

Charles Stark Draper, founder of Draper Laboratory and Institute Professor Emeritus, died in July 1987 at the age of 85. Known as the "father of inertial guidance," Doc Draper evolved the theory, invented and developed the technology, and led the effort which brought inertial navigation to operational usage in aircraft, submarines, missiles, and space vehicles. During his early association with MIT, Dr. Draper's small team of students and technicians expanded to become the Instrumentation Laboratory. In 1973, the laboratory became a separate, independent, nonprofit research and development laboratory located in Cambridge and known as the Charles Stark Draper Laboratory.

In April 1988 George G. Harvey, professor emeritus of Physics, died at the age of 80. Professor Harvey retired in 1973 after nearly 40 years at MIT as a faculty member in the Department of Physics and a long affiliation with the Research Laboratory of Electronics. He was well known for his studies on x-ray scattering and atomic structure as well as for his research in electron microscopy.

Henry G. Houghton, a pioneer of modern meteorology and a researcher and faculty member at MIT since 1928, died in October 1987 at the age of 82. Professor Houghton, who made important contributions in cloud physics and atmospheric radiation, was a founder of the National Center for Atmospheric Research and the first chairman of the University Corporation for Atmospheric Research.

Richard F. Koch, professor emeritus and former faculty member of the Foreign Languages Section in the Department of Humanities, died in October 1987 at the age of 92. Professor Koch joined the MIT faculty in 1939, serving in the foreign languages section until his retirement in 1961.

William T. Lindley, head of Lincoln Laboratory's Microelectronics Group, died in January 1988 at the age of 49. A member of the Lincoln Laboratory staff since 1965, Dr. Lindley was instrumental in developing semiconductor processing technology, including major contributions in semiconductor infrared lasers and detectors.

Jean F. Louis, Professor of Aeronautics and Astronautics at MIT for the past 19 years, died in June at the age of 56 in an automobile accident. Professor Louis was an expert in aircraft propulsion and in magneto-hydrodynamic power generation, which utilizes flowing ionized gases in magnetic fields. He recently had taken a strong interest in means for shifting the technological effort of the United States from military research and development toward space technology and energy systems.

Parry Moon, associate professor emeritus in the Department of Electrical Engineering, died in March 1988 at the age of 90. He was an authority on illuminating engineering, vision, and color. In 1924, he joined the electrical engineering department at MIT as assistant to Vannevar Bush, studying the experimental basis of relativity and high-voltage insulation. He was deeply involved in current research on alternative formulations of electrodynamics at the time of his death.

Fred C. Schweppe, professor of electrical engineering at MIT for 22 years, died in July 1988 at the age of 54. A specialist in electric power systems operations and pricing, he became a full-time member of the MIT faculty in 1968. The breadth of Professor Schweppe's work was shown over the past decade as he and others developed a set of rate structures for the electric power industry described in a recently completed book, *Spot Pricing of Electricity*.

Lt. Charles R. Souter, an MIT graduate who was an instructor in the Naval Reserve Officers Training Corps unit at MIT for the past two years, died in May 1988 at the age of 27 in a car accident. Lt. Souter received the SM in mechanical engineering from MIT in 1983, and was commissioned as an officer in the Navy from the MIT Naval ROTC Program.

G. Gardner Swain, professor emeritus of Chemistry, died in March 1988 at the age of 70. Professor Swain's 40-year career at MIT began in 1946 with an American Chemical Society Fellowship in the laboratory of the late Arthur C. Cope. He was widely known for his research in physical organic chemistry and the mechanisms of reactions.

Statistics for the Year

The following paragraphs report briefly on various aspects of the Institute's activities and operations during 1987-88.

Registration

In 1987-88 student enrollment was 9,565, compared with 9,756 in 1986-87. This total comprises 4,377 undergraduates (compared with 4,443 the previous year), and 5,188 graduate students (compared with 5,313 the previous year). The international student population was 1,880 (not including permanent residents), representing 8 percent of the undergraduate and 30 percent of the graduate population. These students were citizens of 90 countries.

In 1987-88 there were 2,389 women students (1,384 undergraduate and 1,005 graduate) at the Institute, compared with 2,340 (1,295 undergraduate and 1,045 graduate) in 1986-87. In September 1987, 358 first-year women entered MIT, representing 36 percent of the freshman class.

In 1987-88 there were 1,475 minority students (1,236 undergraduate and 239 graduate) at the Institute, compared with 1,344 (1,124 undergraduate and 220 graduate) in 1986-87. Due to changes in Federal guidelines, the numbers beginning 1986-87 include students with permanent residence status. Minority students in 1987-88 included 292 Blacks (non-Hispanic), 19 Native Americans, 305 Hispanics, and 859 Asian Americans. The first-year class entering in September 1987 included 349 minority students, representing 35 percent of the class.

Degrees Awarded

Degrees awarded by the Institute in 1987-88 included 1,150 bachelor's degrees, 1,056 master's degrees, 49 engineer's degrees, 516 doctoral degrees — a total of 2,771.

Student Financial Aid

During the academic year 1987-88 the 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 overall increase in the amount of MIT loans awarded, and Guaranteed Student Loans obtained from commercial sources also showed an increase.

A total of 2,367 undergraduates who demonstrated the need for assistance (54 percent of the enrollment) received \$17,849,000 in grant aid and \$3,213,000 in loans. The total, \$21,062,000, represents a 6 percent increase in aid compared to the previous year.

Grant assistance to undergraduates was provided by \$5,379,000 in income from the scholarship endowment, by \$2,353,000 in outside gifts and Federal allocations to MIT for scholarships, and by \$3,148,000 in direct grants from outside sources, including ROTC, to needy students. In addition, \$6,969,000 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 \$105,000 from unrestricted funds. An additional 687 students received grants from outside agencies, irrespective of need. The undergraduate scholarship endowment was increased by the addition of \$4,416,000 in new funds, raising the principal of the endowment by 10 percent, to \$50,864,000.

Loans totaling \$3,213,000 were made to needy undergraduates — an 11 percent decrease from last year. Of this amount \$735,000 came from the Technology Loan Fund and \$2,478,000 from the National Direct Student Loan Fund. Not included in the foregoing summary is an additional \$5,068,000 obtained by undergraduates from state-administered Guaranteed Loan Programs and other outside sources.

Graduate students obtained \$1,311,000 from the Technology Loan Fund. In addition, \$594,000 was loaned by MIT under the Guaranteed Student Loan Program. The total, \$1,905,000, represents a 52 percent increase over last year's level, which reflects the success of an improved electronic linkage between the Student Financial Aid Office and the Massachusetts Loan Guarantee Office. Graduate students obtained \$3,473,000 from outside sources under the Guaranteed Student Loan Program — about the same as last year. The total loaned by MIT to both graduate and undergraduate students was \$5,118,000, a 5 percent increase over last year.

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

Career Services and Preprofessional Advising

The October slide in the stock market, which dampened the mood on Wall Street for the rest of the year, did little to discourage the economy or the demand for MIT graduates. Even Wall Street came recruiting.

A total of 423 employers came through the office, exactly the same number as the year before. Among them were 19 government agencies, 14 architectural firms, 3 educational organizations seeking teachers, 15 management consulting firms, and 28 banks and investment houses. Interviewing by students was light in the fall term, but by the end of the year, over 1,600 students had had some 9,600 interviews. The student count was the highest ever. The interview count was a drop from the previous year's figure of 10,500, but above the level of 1984-85 or 1985-86.

Salaries offered to graduates this year rose at different rates across the various disciplines. Bachelors in aeronautics and astronautics and in mechanical engineering saw little or no increase over 1986-87. Salaries for Bachelors in electrical engineering rose 3.1 percent over last year, and chemical engineering offers were up 4.3 percent. Bachelor's graduates seeing the highest increase in salaries were those in computer science (up 5.4 percent) and those in management science (up 6.6 percent). Offers to master's graduates were similarly mixed, increasing less than three percent in chemical engineering and mechanical engineering. Doctoral candidates in aeronautics and astronautics and in electrical engineering enjoyed the same rising market as master's candidates in those fields. The median offer to PhDs in electrical engineering — \$54,700 — was up 6.8 percent over 1986-87.

There were 111 MIT applicants to medical school, down from 113 in 1986-87. They included 86 undergraduates, 9 graduate students, and 16 alumni. The number of undergraduates was 22 higher than the previous year, one less than in 1985-86. The number of undergraduate applicants has fluctuated before, so it is too early to tell if this year's count represents a trend. The number of female applicants — 50 in all — was the highest ever, which continues a three year old trend. To date, 80 percent of the undergraduate applicants have been accepted, close to the same percentage accepted by this date last year. By the start of the academic year last September, 91 percent of last year's undergraduate applicants had been accepted. We look forward to similar acceptance rates during the 1988-89 year.

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 \$944,226,000, an increase of 7 percent over 1986-87. Education and general expenses — excluding the direct expenses of departmental and interdepartmental

research and the Lincoln Laboratory — amounted to \$383,403,000 during 1987-88, compared to \$359,896,000 in 1986-87. The direct expenses of departmental and interdepartmental sponsored research on campus increased from \$184,526,000 to \$194,417,000, and direct expenses of the Lincoln Laboratory's sponsored research increased from \$338,062,000 to \$367,156,000.

Current revenues used to meet the Institute's operating expenses totaled \$940,658,000, augmented by \$4,318,000 in unrestricted gifts. After meeting these expenses, a surplus of \$200,000 in current unrestricted gifts was held at year-end.

The major renovation work in the Julius A. Stratton Building (housing the Student Center) and the Plasma Fusion Center continued during the year and the book value of educational plant facilities increased from \$324,406,000 to \$334,150,000.

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 \$1,064,202,000 and a market value of \$1,396,607,000. This compares to book and market values of \$917,464,000 and \$1,396,716,000 last year.

Gifts

Gifts, grants, and bequests to MIT from private donors increased by 22 percent in 1987-88 to a new high of \$83,716,000, as compared to \$68,331,000 in 1986-87. The Alumni Fund reported gifts of \$12,372,000 for the year.

The Institute announced the *Campaign for the future* on October 22, at which time \$210 million in gifts and pledges had already been raised toward the \$550 million goal. By year-end, the total exceeded \$314 million from alumni, friends, corporations and foundations. A large number of events were held both on and off campus to inform our donors of the quality of the Institute's programs and more are planned for the coming year. The Campaign is primarily directed at increasing endowment, particularly for professorships, student aid, research and unrestricted funds. The many volunteers, faculty and staff that are devoting their efforts to the Campaign provides optimism for continued success.

Physical Plant and Campus Environment

Major construction activities this year included substantial completion of accommodations for an additional 29 graduate students at Ashdown House and significant progress on the renovation of the Stratton Building, scheduled to reopen in the fall. Preliminary design was completed for the renovation of 143 Albany Street into housing for 185 married and single graduate students, design was initiated for an addition to Building 7 that will allow for expansion of the Rotch Library, and a planning study in preparation for the design of a new biology building to be constructed on a portion of the former TRW/Carr Fastener site was begun.

This year the Institute continued its commitment to energy conservation and associated cost avoidance by initiating work on a formal retrofit program in conjunction with Cambridge Electric Light Company's electricity conservation rebate program. Over the next year, we anticipate carrying out \$3.7 million of construction that will touch almost every room on campus. Installation of new, more efficient electric devices, controls, motors, and lighting equipment will generate savings and rebates with a value of over \$1.5 million annually. During the first three years while the cost of construction is being amortized, the Institute's net energy cost reduction will average approximately \$500,000 per year. Beginning in 1993, essentially all of the savings will be available for other purposes.

Significant progress was also made this year on two important campus environmental health and safety issues, namely, the identification and removal or encapsulation of asbestos-containing materials and the identification and removal of polychlorinated biphenyl (PCB)-containing electrical equipment. In addition, a renewed effort was undertaken to clear Institute corridors of all obstructions. The Safety Office, with the help of Physical Plant, the Property Office, and departmental and laboratory personnel, completed a highly successful campus-wide corridor clean-up prior to the end of the year.

Personnel Changes

CORPORATION

DEATHS

James R. Killian, Jr.
Life Member, Emeritus

Walter J. Beadle
Life Member, Emeritus

CHANGES OF APPOINTMENT

Semon E. Knudsen
Life Member, Emeritus

ELECTIONS

Robert A. Charpie
Member

Herbert H. Dow
Member

Joseph G. Gavin, Jr.
Life Member

Margaret Coleman Haas
Member

David H. Koch
Member

Agnus N. MacDonald
Member

H. DuBose MacDonald
Member

Robert A. Muh
Member

Megan J. Smith
Member

Frank S. Wyle
Member

MEMBER EX-OFFICIO

Emily V. Wade
President
Alumni Association

TERMS EXPIRED

W. H. Krome George
Member

Floyd A. Lyon
Member

Denman D. McNear
Member

Rhonda E. Peck
Member

FACULTY

DEATHS

Jean F. Louis
Department of Aeronautics
and Astronautics

Fred C. Schweppe
Department of Electrical
Engineering and Computer
Science

C. Stark Draper
Department of Aeronautics and
Astronautics

RETIREMENTS

Martin A. Abkowitz
Department of Ocean
Engineering

Charles Batterman
Athletic Department

John M. Buchanan
Department of Biology

Martin Dyck
School of Humanities and
Social Science

Richard Filipowski
Department of Architecture

David H. Frisch
Department of Physics

Wesley L. Harris
Department of Aeronautics and
Astronautics

Richard D. Schafer
Department of Mathematics

Malcom W. P. Strandberg
Department of Physics

Emmett A. Witmer
Department of Aeronautics and
Astronautics

RESIGNATIONS

Professor

John L. Buttrick
Professor
Music and Theater Arts Section

Richard Kayne
Professor
Department of Linguistics
and Philosophy

Robert C. Merton
Professor
Sloan School of Management

Daniel G. Quillen
Professor
Department of Mathematics

Robert I. Rotberg
Professor
History Section

Donald R. Uhlmann
Professor
Department of Materials
Science and Engineering

Christopher T. Walsh
Professor
Department of Chemistry

Associate Professor

Peter S. Buck
Associate Professor
Program in Science,
Technology, and Society

Kathryn J. Creelius
Associate Professor
Foreign Languages and
Literatures Section

John Dreher
Associate Professor
Department of Physics

Lance A. Glasser
Associate Professor
Department of Electrical
Engineering and Computer
Science

Luigi Rizzi
Associate Professor
Department of Linguistics
and Philosophy

Marsha R. Rosner
Associate Professor
Department of Applied
Biological Sciences

Emma G. Rothschild
Associate Professor
Program in Science,
Technology, and Society

Richard S. Ruback
Associate Professor
Sloan School of Management

Sharon Traweek
Associate Professor
Anthropology/Archaeology
Program

Anne M. Wagner
Associate Professor
Department of Architecture

M. Anthony Wong
Associate Professor
Sloan School of Management

Assistant Professor

Bruce E. Beall
Assistant Professor
Athletic Department

Lauren A. Benton
Assistant Professor
Department of Urban Studies
and Planning

Joseph Brami
Assistant Professor
Foreign Languages and
Literatures Section

Renee Fitts
Assistant Professor
Department of Applied
Biological Sciences

Robert T. Hanlon
Assistant Professor
Department of Chemical
Engineering

Roger T. Howe
Assistant Professor
Department of Electrical
Engineering and Computer
Science

Daniel Metlay
Assistant Professor
Department of Political
Science

Pierre Regibeau
Assistant Professor
Sloan School of Management

R. Erik Spjut
Assistant Professor
Department of Materials
Science and Engineering

Yasser A. Tabbaa
Assistant Professor
Department of Architecture

Roger Thompson
Assistant Professor
History Section

Er-Cheng Tsai
Assistant Professor
Department of Mathematics

Joanna Waley-Cohen
Assistant Professor
History Section

William R. Young
Assistant Professor
Department of Earth,
Atmospheric, and Planetary
Sciences

PROMOTIONS

To Professor

Dimitri A. Antoniadis
Professor
Department of Electrical
Engineering and Computer
Science

Arnold I. Barnett
Professor
Sloan School of Management

Moshe E. Ben-Akiva
Professor
Department of Civil
Engineering

Stephen Benton
Professor
Media Arts and Sciences
Section

Suzanne H. Corkin
Professor
Department of Brain and
Cognitive Sciences

Thomas W. Eagar
Professor
Department of Materials
Science and Engineering

Stephen C. Graves
Professor
Sloan School of Management

James T. Higginbotham
Professor
Department of Linguistics
and Philosophy

Paul G. Horwich
Professor
Department of Linguistics
and Philosophy

Jean E. Jackson
Professor
Anthropology/Archaeology
Program

Alexander M. Klibanov
Professor
Department of Chemistry

Marten Landahl
Professor
Department of Aeronautics
and Astronautics

James B. Orlin
Professor
Sloan School of Management

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

Robert T. Sauer
Professor
Department of Biology

Yosef Sheffi
Professor
Department of Civil
Engineering

Ulrich W. Suter
Professor
Department of Chemical
Engineering

Jean Tirole
Professor
Department of Economics

Shimon Ullman
Professor
Department of Brain
and Cognitive Sciences

Cardinal Warde
Professor
Department of Electrical
Engineering and Computer
Science

To Associate Professor

Ronald G. Ballinger
Associate Professor
Department of Nuclear
Engineering

Ranko Bon
Associate Professor
Department of Architecture

Rodney A. Brooks
Associate Professor
Department of Electrical
Engineering and Computer
Science

Sylvia T. Ceyer
Associate Professor
Department of Chemistry

David J. Edell
Associate Professor
Harvard-MIT Division of Health
Sciences and Technology

Suzanne Flynn
Associate Professor
Foreign Languages and
Literatures Section

Robert M. Freund
Associate Professor
Sloan School of Management

Lorna J. Gibson
Associate Professor
Department of Civil
Engineering

David K. Gifford
Associate Professor
Department of Electrical
Engineering and Computer
Science

Shafi Goldwasser
Associate Professor
Department of Electrical
Engineering and Computer
Science

Robert J. Hansman, Jr.
Associate Professor
Department of Aeronautics
and Astronautics

T. Alan Hatton
Associate Professor
Department of Chemical
Engineering

Kip V. Hodges
Associate Professor
Department of Earth,
Atmospheric, and Planetary
Sciences

Chi-Fu Huang
Associate Professor
Sloan School of Management

Dale Karr
Associate Professor
Department of Ocean
Engineering

Judith A. Lachman
Associate Professor
Sloan School of Management

Bruce R. Musicus
Associate Professor
Department of Electrical
Engineering and Computer
Science

Keith A. Nelson
Associate Professor
Department of Chemistry

Peter Perdue
Associate Professor
History Section

David H. Raulet
Associate Professor
Department of Biology

Marsha R. Rosner
Associate Professor
Department of Applied
Biological Sciences

Candace L. Royer
Associate Professor
Athletic Department

Lynne B. Sagalyn
Associate Professor
Department of Urban Studies
and Planning

Charles G. Sodini
Associate Professor
Department of Electrical
Engineering and Computer
Science

Robert J. Thomas
Associate Professor
Sloan School of Management

Carl V. Thompson
Associate Professor
Department of Materials
Science and Engineering

Lloyd N. Trefethen
Associate Professor
Department of Mathematics

John M. Tsitsiklis
Associate Professor
Department of Electrical
Engineering and Computer
Science

Anne M. Wagner
Associate Professor
Department of Architecture

Jeremy M. Wolfe
Associate Professor
Department of Brain and
Cognitive Sciences

Dick K. Yue
Associate Professor
Department of Ocean
Engineering

CHANGES OF APPOINTMENT

Yet-Ming Chiang
Mitsui Career Development
Assistant Professor
Department of Materials
Science and Engineering

Michael J. Cima
Norton Assistant Professor
Department of Materials
Science and Engineering

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

Gregory Duckworth
Visiting Assistant Professor
Department of Earth,
Atmospheric, and Planetary
Sciences

Kenneth A. Froot
Ford International
Assistant Professor
Sloan School of Management

Lorna Gibson
Gilbert W. Winslow Career
Development
Associate Professor
Department of Civil
Engineering

Michael B. Giles
Esther and Harold E. Edgerton
Assistant Professor
Department of Aeronautics
and Astronautics

Edward M. Greitzer
H. N. Slater Professor
Department of Aeronautics
and Astronautics

W. Eric Grimson
Matsushita Assistant Professor
of Electrical Engineering
Department of Electrical
Engineering and Computer
Science

John H. Harbison
Head of the Music Section and
Class of 1949 Professor
of Music
School of Humanities and
Social Science

Daniel E. Hastings
Charles Stark Draper
Assistant Professor
Department of Aeronautics
and Astronautics

T. Alan Hatton
Class of 1922
Associate Professor
Department of Chemical
Engineering

Arnoldo C. Hax
Alfred P. Sloan Professor of
Management and Deputy Dean
Sloan School of Management

Nicole Herbots
IBM Career Development
Assistant Professor
Department of Materials
Science and Engineering

James Howe
Head of the
Anthropology/Archaeology
Program and Associate
Professor of Anthropology

Erich P. Ippen
Elihu Thompson Professor
of Electrical Engineering
Department of Electrical
Engineering and Computer
Science

Peter J. Kempthorne
Associate Professor of
Management Science
Sloan School of Management

Philip Khoury
Associate Dean
and Associate Professor
of History
School of Humanities and
Social Science

Hae-Seung Lee
Joseph F. and Nancy P. Keithly
Career Development Assistant
Professor of Electrical
Engineering
Department of Electrical
Engineering and Computer
Science

J. David Litster
Professor of Physics and
Director of the Francis Bitter
National Magnet Laboratory

Travis R. Merritt
Associate Dean and Section
Head, Undergraduate Academic
Support in Office of the Dean
for Student Affairs and
Professor of Literature in
School of Humanities and
Social Science

Robert S. Pindyck
Mitsubishi Bank Professor
in Finance
Sloan School of Management

Patricia C. Renaud
Esther and Harold E. Edgerton
Assistant Professor
Department of Mechanical
Engineering

Michael F. Rubner
IBM Career Development
Assistant Professor
Department of Materials
Science and Engineering

David A. Rudman
Pirelli Assistant Professor
Department of Materials
Science and Engineering

Martin F. Schlecht
Esther and Harold E. Edgerton
Assistant Professor of
Electrical Engineering
Department of Electrical
Engineering and Computer
Science

K. Barry Sharpless
Arthur C. Cope Professor
Department of Chemistry

Abraham J. Siegel
Howard W. Johnson Professor
of Management
Sloan School of Management

Isadore M. Singer
Institute Professor

Jean-Jacques Slotine
Henry L. Doherty
Assistant Professor
Department of Mechanical
Engineering

David H. Staelin
Cecil H. Green Professor
of Electrical Engineering
Department of Electrical
Engineering and Computer
Science

Peter Temin
Associate Department Head
and Professor of Economics
Department of Economics

Lester C. Thurow
Dean and Professor of the
Sloan School of Management

Glen L. Urban
Dia-Ichi Kangyo Bank Professor
of Management and Deputy Dean
Sloan School of Management

Lena Valavani
Boeing Assistant Professor
Department of Aeronautics
and Astronautics

Andreas H. von Flotow
Charles Stark Draper
Assistant Professor
Department of Aeronautics
and Astronautics

Myron Weiner
Ford Professor of Political
Science and Director of Center
for International Studies

Harry West
Mitsui Career Development
Assistant Professor
Department of Mechanical
Engineering

Jacob K. White
Analog Devices Career
Development Assistant
Professor
Department of Electrical
Engineering and Computer
Science

Mark S. Wrighton
Department Head and Professor
Department of Chemistry

FACULTY NEW APPOINTMENTS

Professor

Drew Fudenberg
Professor
Department of Economics

Leon R. Glicksman
Professor
Department of Architecture

Robert Mac Pherson
Professor
Department of Mathematics

Ruth Perry
Professor
School of Humanities and
Social Science

Raymond A. Plumb
Professor
Department of Earth,
Atmospheric, and Planetary
Sciences

Joanne Stubbe
Professor
Department of Chemistry

Kenneth N. Wexler
Professor
Department of Brain and
Cognitive Sciences

Associate Professor

Henrik Schmidt
Associate Professor
Department of Ocean
Engineering

Assistant Professor

Anant Agarwal
Assistant Professor
Department of Electrical
Engineering
and Computer Science

Philippe Aghion
Assistant Professor
Department of Economics

Lauren A. Benton
Assistant Professor
Department of Urban Studies
and Planning

Mary Boyce
Assistant Professor
Department of Mechanical
Engineering

David O. Brink
Assistant Professor
Department of Linguistics
and Philosophy

Peggy Cebe
Assistant Professor
Department of Materials
Science and Engineering

Wujin Chu
Assistant Professor
Sloan School of Management

Munther A. Dahleh
Assistant Professor
Department of Electrical
Engineering and Computer
Science

Jesus A. Del Alamo
Assistant Professor
Department of Electrical
Engineering and Computer
Science

Jonathan A. Fox
Assistant Professor
Department of Political
Science

Katherine Freese
Assistant Professor
Department of Physics

Karen K. Gleason
Herman P. Meisner
Class of 1929
Assistant Professor
Department of Chemical
Engineering

Martha L. Gray
J. W. Kieckhefer
Assistant Professor
Department of Electrical
Engineering and Computer
Science

John M. Graybeal
Assistant Professor
Department of Physics

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

Jeffrey Hamilton
Assistant Professor
Athletic Department

Michael O. Hardimon
Assistant Professor
Department of Linguistics
and Philosophy

Paul Hoffman
Assistant Professor
Department of Linguistics
and Philosophy

Ellen M. Immergut
Assistant Professor
Department of Political
Science

Belgacem Jery
Assistant Professor
Department of Aeronautics and
Astronautics

Michael I. Jordan
Assistant Professor
Department of Brain and
Cognitive Sciences

Hasan Kayali
Assistant Professor
History Section

Chris F. Kemerer
Assistant Professor
Sloan School of Management

Leslie A. Kolodziejcki
Assistant Professor
Department of Electrical
Engineering and Computer
Science

Harilaos N. Koutsopoulos
Assistant Professor
Department of Civil
Engineering

Arthur D. Lander
Assistant Professor
Department of Brain and
Cognitive Sciences

Peter T. Lansbury
Assistant Professor
Department of Chemistry

Kim A. Lewis
Assistant Professor
Department of Applied
Biological Sciences

John H. Lienhard
Assistant Professor
Department of Mechanical
Engineering

Gregory J. Mehos
Assistant Professor and
Station Director, School of
Chemical Engineering Practice
Department of Chemical
Engineering

Uday S. Mehta
Assistant Professor
Department of Political
Science

Simon G. J. Mochrie
Assistant Professor
Department of Physics

David C. Page
Assistant Professor
Department of Biology

Francesco A. Passanti
Assistant Professor
Department of Architecture

Michael A. Rappa
Assistant Professor
Sloan School of Management

Pierre Regibeau
Assistant Professor
Sloan School of Management

Donald C. Rio
Assistant Professor
Department of Biology

David Scharfstein
Assistant Professor
Sloan School of Management

Andrea Shepard
Assistant Professor
Department of Economics

Hermann Steller
Assistant Professor
Department of Brain and
Cognitive Sciences

Roger Thompson
Assistant Professor
History Section

Joanna Waley-Cohen
Assistant Professor
History Section

Van J. Wedeen
Assistant Professor
Whitaker College of Health,
Sciences, Technology, and
Management

Lawrence M. Wein
Assistant Professor
Sloan School of Management

Jonathan S. Wurtele
Assistant Professor
Department of Physics

Helmut Zarbl
Assistant Professor
Program in Toxicology

Adjunct Professor

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

Robert A. Laudise
Adjunct Professor
Department of Materials
Science and Engineering

Visiting Professor

Jorge Andrade
Visiting Professor
Department of Architecture

Guenther Behnisch
Visiting Professor
Department of Architecture

Michel P. Bouchon
Visiting Professor
Department of Earth,
Atmospheric, and Planetary
Sciences

Harold D. Brody
Visiting Professor
Department of Materials
Science and Engineering

Peter Brownell
Visiting Professor
Sloan School of Management

Samprit Chatterjee
Visiting Professor
Sloan School of Management

Ken P. Chong
Visiting Professor
Department of Civil
Engineering

Geoffrey R. Court
Visiting Professor
Department of Physics

Jean-Loup Delcroix
Visiting Professor
Department of Electrical
Engineering and Computer
Science

Odd M. Faltinsen
Visiting Professor
Department of Ocean
Engineering

Yeheskel Shraga Halpern
Visiting Professor
Department of Biology

Elhanan Helpman
Visiting Professor
Department of Economics

Peter Howitt
Visiting Professor
Department of Economics

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

James Lowell
Crosby Visiting Professor
Department of Earth,
Atmospheric, and Planetary
Sciences

Rajnish Mehra
Visiting Professor
Sloan School of Management

Gary G. Nelson
Visiting Professor
Air Force Aerospace Studies

James F. O'Gorman
Visiting Professor
Department of Architecture

J. Theodoor G. Overbeek
Visiting Professor
Department of Materials
Science and Engineering

Louis Padulo
Visiting Professor
Media Arts and Sciences
Section

Victor Perez-Diaz
Visiting Professor
Department of Political
Science

Hormozd B. Poorooshab
Visiting Professor
Department of Civil
Engineering

Melvin R. Ramey
Visiting Professor
Department of Mechanical
Engineering

Ignacio Rodriguez-Iturbe
Visiting Professor
Department of Civil
Engineering

Pradeep K. Rohatgi
Visiting Professor
Department of Materials
Science and Engineering

Albe Sangiovanni-Vincentelli
Visiting Professor
Department of Electrical
Engineering and Computer
Science

Robert W. Scherer
Visiting Professor
Naval Science

Manfred Specht
Visiting Professor
Department of Civil
Engineering

Robert A. Taggart, Jr.
Visiting Professor
Sloan School of Management

Stavros B. Thomadakis
Visiting Professor
Sloan School of Management

Daniel C. Tsui
Visiting Professor
Department of Physics

Ka Kit Tung
Visiting Professor
Department of Earth,
Atmospheric, and Planetary
Sciences

Thomas Vargish
Visiting Professor
Sloan School of Management

Rochus E. Vogt
Visiting Professor
Department of Physics

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

Nan-ming Zhao
Visiting Professor
Department of Nuclear
Engineering

Visiting Associate Professor

Gian Paolo Beretta
Visiting Associate Professor
Department of Mechanical
Engineering

Mark A. Cane
Visiting Associate Professor
Department of Earth,
Atmospheric, and Planetary
Sciences

Eliana Cardoso
Visiting Associate Professor
Department of Economics

Wayne Chudyk
Visiting Associate Professor
Department of Civil
Engineering

Marie A. Cossette
Visiting Associate Professor
Media Arts and Sciences
Section

Roberto R. De Avillez
Visiting Associate Professor
Department of Materials
Science and Engineering

Charles N. Esimai
Visiting Associate Professor
Department of Materials
Science and Engineering

Jane Fox
Visiting Associate Professor
Department of Earth,
Atmospheric, and Planetary
Sciences

William C. Higginson
Visiting Associate Professor
Media Arts and Sciences
Section

Glenn R. Ierley
Visiting Associate Professor
Department of Earth,
Atmospheric, and Planetary
Sciences

Marija Ilic
Visiting Associate Professor
Department of Electrical
Engineering and Computer
Science

Janet L. Kolodner
Visiting Associate Professor
Department of Electrical
Engineering and Computer
Science

Joseph Kost
Visiting Associate Professor
Department of Urban Studies
and Planning

Claire L. Lang
Visiting Associate Professor
Department of Urban Studies
and Planning

Per Olov Lindberg
Visiting Associate Professor
Sloan School of Management

Rajnish Mehra
Visiting Associate Professor
Sloan School of Management

Hameed Metghalchi
Visiting Associate Professor
Department of Mechanical
Engineering

Yuzo Ohnishi
Visiting Associate Professor
Department of Civil
Engineering

Janice A. Phillips
Visiting Associate Professor
Department of Chemical
Engineering

Randy Ross
Visiting Associate Professor
Department of Physics

Marilyn C. Schaffer
Visiting Associate Professor
Media Arts and Sciences
Section

Thomas I. Selling
Visiting Associate Professor
Sloan School of Management

Visiting Assistant Professor

Gordon S. Bates
Visiting Assistant Professor
Department of Chemistry

Barry Bergdoll
Visiting Assistant Professor
Department of Architecture

Hasan Kayali
Visiting Assistant Professor
History Section

Sue Mc Neil
Visiting Assistant Professor
Department of Civil
Engineering

Antonio S. Mello
Visiting Assistant Professor
Sloan School of Management

William W. Quivers
Visiting Assistant Professor
Department of Physics

James R. Richardson
Visiting Assistant Professor
Department of Urban Studies
and Planning

David H. Romer
Visiting Assistant Professor
Department of Economics

Egon Schulte
Visiting Assistant Professor
Department of Mathematics

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

Robert S. Steedman
Visiting Assistant Professor
Department of Civil
Engineering

Eva Tardos
Visiting Assistant Professor
Department of Mathematics

AWARD

Jay W. Forrester
Germeshausen Professor
Sloan School of Management

ADMINISTRATION

RETIREMENTS

James F. Baker, Jr.
Lieutenant
Campus Police

Marshall V. Cheverie
Lieutenant
Campus Police

Mary Frances Daly
Administrative Assistant
Quarter Century Club

Barbara A. Durland
Assistant to the Vice
President, for Information
Systems Resource Development
Vice President

Robert E. Durland
Manager, Furniture and
Furnishings
Office of Laboratory Supplies

Phyllis M. Gallant
Assistant to the Director
of Development Services
Office of Development Services

Richard Higham
Senior Personnel Officer
Personnel Office

Estil Jones
Assistant Manager, Campus
Activities Complex
Superintendent's Office

Mary M. Kelly
Assistant to the Director
for Data Base Management
and Freshman Processing
Admissions Office

John P. Leonard
Associate Comptroller
Comptroller's Accounting
Office

Muriel J. Lewis
Librarian
Libraries

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

John G. Mahoney
Assistant Director Office
of Sponsored Programs
Office of Sponsored Programs

John R. Martuccelli
Director,
Engineering Intern Program
School of Engineering

Ann S. Mc Cormick
Assistant Bursar,
Loan Collection
Office of the Bursar

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

John H. Murphy
Equipment Manager
Athletic Department

Elizabeth A. O'Brien
Administrative Officer
Environmental Medical Service

James Olivieri
Chief
Campus Police

Leo S. Plagenza
Utilities Supervisor,
Electrical Shop
Superintendent's Office

Miriam Sherburne
Advisor, Master's Program
Sloan School of Management

Horace M. Smith
Administrator,
Electrical Engineering
Department of Electrical
Engineering and Computer
Science

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

RESIGNATIONS

Janet E. Abbate
Systems Programmer
Operations and Systems

Sarah Abrams
Staff Writer/Editor
Office of Communications

Mark S. Ackerman
Senior Application Programmer
Project Athena

Edward Agro
Editor
MIT Press

Robin Alberts
Route Supervisor,
Building Services
Physical Plant

Donald C. Alcaide
Applications Coordinator
Office of Facilities
Management Systems

Nelson Armstrong
Area Director, Alumni Fund
Alumni Association

Laura J. Ayr
Journals Advertising and
Exhibits Manager
MIT Press

Alison B. Bass
Staff Writer/ Editor
Alumni Association

Martha L. Bertrand
Director of Donor Relations
and Campus Visits
Office of Donor Relations

William J. Billings
Administrative Officer
Department of Physics

Robert E. Bolick
Acquisition Editor
MIT Press

Paulette Boudreaux
Staff Writer/ Editor
Public Relations Services

Mimi S. Braverman
Editor
MIT Press

Roberta N. Brawer
Applications Programmer
Department of Electrical
Engineering and Computer
Science

Neil G. Buckley, Jr.
Administrative Manager
Sloan School of Management

Patricia H. Bullock
Budget Officer
Fiscal Planning and Budget
Office

Dennis Capps
Systems Programmer
Operations and Systems

Leslie M. Cariani
Donor Relations Coordinator
Director Major Gifts

Joseph J. Casarano, Jr.
Institute Auditor
Audit Division

Marjorie Chryssostomidis
Librarian
Libraries

James Y. Chu
Analyst Programmer
Purchasing and Stores

Barbara S. Chuck
Staff Associate, Undergraduate
Academic Support
Dean for Student Affairs

Marcia C. Clifford
Auditor
Audit Division

Anthony Colozzi
Assistant to the Director for
Operations
Department of Electrical
Engineering and Computer
Science

Ramona Connelly
Librarian
Libraries

Nadine H. Cruz
Analyst Programmer
Administrative Systems
Development

Thomas R. Curran
Property Auditor
Property Office

Marie A. Danziger
Assistant Dean for Student
Affairs, UASO
Dean for Student Affairs

Rebecca A. Daw
Designer
MIT Press

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

Joanne De Siato
Child Care Administrator
Child Care Office

Gary J. Desgroseilliers
Senior Industrial Liaison
Officer
Industrial Liaison Program

Judith R. Dortz
Administrative Officer
Department of Earth,
Atmospheric, and Planetary
Sciences

Edwin E. Drakes
Night Supervisor, Campus
Activities Complex
Superintendent's Office

Jaunette T. Eaglesfield
Librarian
Libraries

Alana J. Erickson
Deployment Manager
Project Athena

Mark E. Ertel
Advisor to Fraternity and
Independent Living Groups
Dean for Student Affairs

Rhoda Fischer
Staff Writer/ Editor
History Section

Charles H. Fuller
Administrative Officer
Writing Program

Rus Gant
Senior Applications
Development Programmer
Project Athena

Steven Gass
Librarian
Libraries

Joyce Taylor Gibson
Director, Office of Minority
Education
Dean for Student Affairs

William A. Gilbert
Administrative Staff
Whitaker College of Health
Sciences,
Technology, and Management

Xev Gittler
Systems Programmer
Harvard-MIT Health,
Sciences and Technology

Luz M. Gordillo
Analyst Programmer
Administrative Systems
Development

David G. Graham
Route Supervisor,
Building Services
Superintendent's Office

Michael R. Gretzinger
Systems Programmer
Project Athena

Nancy M. Hack
Graduate Alumni Program
Director
Alumni Association

Harold C. Haizlip
Executive Director/Carnegie
Sponsored Quality Education
for Minorities Project
Dean for Student Affairs

Susan J. Halsted
Group Sales Manager
Endicott House

Christopher M. Hancock
Applications Development
Programmer
Project Athena

David M. Hardy
Analyst Programmer
Office of Facilities
Management Systems

James A. Herbeck
Consultant
Project Athena

Armando Hernandez
Applications Development
Programmer
Music and Theater Arts Section

Brian D. Herr
Operations and Administration
Manager
Telecommunications Systems

Kate S. Herzog
Librarian
Libraries

William F. Hogue
Assistant Director, Project
Athena
Project Athena

Candace K. Hopkins
Analyst Programmer
Alumni Association

Arlyne A. Jackson
Associate Head Librarian
Libraries

C. Nicholas James
Manager, Animal Facilities
Division of Comparative
Medicine

Mark Johnson
Analyst Programmer
Office of Facilities
Management Systems

Lucie M. Juneau
Staff Writer/ Editor
Industrial Liaison Program

Karen A. Kahn
Technical Writer
Administrative Systems
Development

Bernadett J. Kay
Systems Programmer
Operations and Systems

Dina K. Kazis
Assistant Auditor
Audit Division

Patricia A. Knieriem
Manager, Parking and Traffic
Division
Campus Police

Elaine M. Konopka
Staff Writer/ Editor
Dean for Student Affairs

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

Sandra Wells Ladd
Analyst Programmer
Administrative Systems
Development

David Laughridge
Supervisor, Illustration
Service
Graphic Arts

Paul C. Leach
Regional Director for the
Alumni Association

Frank F. Lee
Staff Administrator,
Purchasing and Stores
Office of Laboratory Supplies

Susan J. Lee
Administrative Assistant to
Director
Industrial Liaison Program

Mark H. Levine
Senior Systems Programmer
Project Athena

Peter Levine
Systems Programmer
Project Athena

Katharyn L. Lieben
Documentation Manager
Project Athena

Suzana T. Lisanti
Senior Technical Writer
Information Services

Kevin E. Lonnie
Senior Industrial Liaison
Officer
Industrial Liaison Program

Joseph F. Luszcz
Assistant to the Bursar,
Information Systems
Office of the Bursar

Eva Marie Lyons
Coordinator of Enrollment
Service Operations
Medical Department

Stephen P. Mac Gillivray
Analyst Programmer
Administrative Systems
Development

Richard Mac Millan
Associate Director,
Council for the Arts At MIT
Office of the President

Janet Macy
Analyst Programmer
Administrative Systems
Development

James J. Mahoney
Assistant Auditor
Audit Division

Karl Leroy Mapes
Area Manager
Administrative Systems
Development

Maria Marangiello
Administrative Assistant
Department of Civil
Engineering

Steven P. Margossian
Advisor to Fraternity and
Independent Living Groups
Dean for Student Affairs

Joseph J. Martori
Associate Secretary of the
Alumni Association

James Edward Maslow
Technology Licensing Officer
Technology Licensing Office

Sylvia A. Mc Dowell
Librarian
Libraries

Linda B. Merims
Senior Consultant
Project Athena

Bruce A. Mogayzel
Associate Director,
Alumni Information Management
Alumni Association

Richard C. Moore
Systems Programmer
Operations and Systems

Valderia A. Moore
Coordinator, Information Ouput
Alumni Association

Glenn H. Myers
Analyst Programmer
Comptroller's Accounting
Office

Elaina M. Myrinx
District Director
National Campaign Office

Ramesh Natarajan
Senior Consultant
Information Services

Margaret L. Nelson
Assistant to the Bursar-Loan
Collections
Office of the Bursar

Ronald Newman
Systems Programmer
Project Athena

Susan K. Nutter
Associate Director for
Collection Management
and Technology
Libraries

Carol M. O'Connor-Fischer
Publicity Manager
MIT Press

Patricia O'Connor
Activities Assistant,
Campus Center Complex
Campus Activities Complex

Samuel Peter Osgood
Application Engineer
Project Athena

Elizabeth E. Pessek
Archival / Manuscript
Specialist
Libraries

Theresa A. Pyatt
Administrative Assistant
Department of Civil
Engineering

Mark Rakatansky
Acquisition Editor
MIT Press

Jeffrey G. Rimpas
Marketing Coordinator
Medical Department

W. Larry Ritchie
Industrial Liaison Officer
Industrial Liaison Program

Rosanne V. Rizzi
Administrative Staff
Committee on the Visual Arts

Laura M. Robinson
Senior Industrial Liaison
Officer
Industrial Liaison Program

Julia M. Salas
Journals Editorial and
Production Manager
MIT Press

Russell M. Sasnett
Applications Development
Programmer
Project Athena

Trudihope Schlomowitz
Subsidiary Rights Manager
MIT Press

Bonnie F. Sestito
Supervisor, Publications and
Software
Information Services

Dorothy Shamonsky
Applications Development
Programmer
Project Athena

Margaret A. Shaw
Analyst Programmer
Administrative Systems
Development

Thomas M. Shea
Area Manager
Administrative Systems
Development

Julie R. Shepler
Direct Marketing Manager
Center for Advanced
Engineering Study

Michael A. Silvia
Assistant Director,
Subcontracting and Government
Relations
Purchasing and Stores

Dallas M. Slawter
Assistant to the Director, OME
Dean for Student Affairs

Nancy R. Spears
Assistant to the Secretary
of the Corporation
Office of the President

Sambasivan Suresh
Coordinator,
Facilities Maintenance
Division of Comparative
Medicine

George S. Tarasenko
Systems Programmer
Administrative Systems
Development

G. Winfield Treese
Systems Programmer
Project Athena

John F. Valleli
Personnel Administrator
Department of Brain and
Cognitive Sciences

Marie T. Vander Sande
Senior Industrial Liaison
Officer
Industrial Liaison Program

Maryglenn Vincens
Senior Staff Associate,
Undergraduate Academic
Support Office
Dean for Student Affairs

Marina X. Vrouvlianis
Analyst Programmer
Administrative Systems
Development

Robin M. Wagner
Assistant to the Dean
School of Engineering

Lisa J. Walker
Analyst Programmer
Comptroller's Accounting
Office

Jacalyn D. Walker-Sharp
Coordinator, Management of
Technology Program
Sloan School of Management

Nancy B. Weiland
Marketing and Enrollment
Administrator
Medical Department

Amy J. Weiner
Computer Operations
Coordinator
Whitaker College of Health,
Sciences Technology and
Management

Elissa R. Weitzman
Technical Writer
Information Services

Julia A. Werbinski
Assistant Auditor
Audit Division

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

Nancy H. Wilson
Senior Analyst Programmer
Administrative Systems
Development

Ellen Y. Yen
Librarian
Libraries

Judith E. Young
Analyst Programmer
Administrative Systems
Development

Stephen H. Young
Supervisor,
Mechanical Services
Physical Plant

Robert E. Zaret
Consultant
Information Services

NEW APPOINTMENTS

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

Jean F. Anderson
Administrative Assistant
Sloan School of Management

Susan L. Anderson
Area Director, Alumni Fund
Alumni Association

Jill A. Appel
Technical Supervisor
Information Services

Jennifer G. Archibald
Graduate Alumni Program
Director
Alumni Association

Joseph E. Baclawski
Industrial Liaison Officer
Industrial Liaison Program

Jeanne P. Benedict
Marketing Manager
Center for Advanced
Engineering Study

James F. Bixby
Senior Systems Programmer
Lincoln Fiscal Office

Cheryl L. Blankenship
Associate Bursar,
Student Services
Office of the Bursar

Dennis R. Bouley
Production Analyst
Operations and Systems

Hope E. Brand
Librarian
Libraries

Bruce E. Brown
Administrative Officer
Division of Comparative
Medicine

Olga Brown
Systems Programmer
Writing Program

Neil G. Buckley, Jr.
Administrative Manager
Sloan School of Management

Martin H. Bunshaft
Consultant
Information Services

Mary A. Calderazzo
Financial Administrator
Office of the Provost

John M. Capomaccio
Route Supervisor,
Building Services
Physical Plant

Calestine M. Carney
Administrative Assistant
Department of Electrical
Engineering and Computer
Science

Sarah M. Carothers
District Director
National Campaign Office

Robert P. Casey
Staff Accountant
Comptroller's Accounting
Office

Estelle M. Cashman
Campus Visits Coordinator
National Campaign Office

Collette Chambers
Assistant to the Director
Telecommunications Systems

Maynard E. Charles
Staff Accountant
Comptroller's Accounting
Office

Kelly F. Chen
Analyst Programmer
Administrative Systems
Development

Marjorie Chryssostomidis
Librarian
Libraries

James Y. Chu
Analyst Programmer
Purchasing and Stores

Robert N. Clark, Jr.
Assistant Auditor
Audit Division

Allison P. Cocuzzo
Publications Manager
Center for Advanced
Engineering Study

Nancy Collins
Personnel Assistant
Personnel Office

Carolyn Colt
Senior Business Systems
Analyst
Administrative Systems
Development

Donald R. Comeau
Property Administrator
Lincoln Fiscal Office

Susan E. Crowley
Administrative Assistant
to the Senior Vice President
Office of the Senior Vice
President

Mark L. Curby
Consultant
Information Services

William Curr
Operations Administrator
Department of Biology

Jill E. Damashek
Financial Administrator
Information Services

Lee-Ann L. Day
Major Gifts Officer
Director, Major Gifts

David P. Diamond
Detective
Campus Police

Alfred R. Doig, Jr.
District Director
National Campaign Office

William F. Downes
Area Director, Alumni Fund
Alumni Association

Gerald P. Doyle
Sergeant
Campus Police

Anne L. Drazen
Director of Information
Systems
Sloan School of Management

John E. Driscoll
Lieutenant
Campus Police

Stephen P. Dyer
Senior Systems Programmer
Project Athena

Julie A. Eastman
Assistant to Director of
Major Gifts for Donor Relation
Director Major Gifts

Lawrence W. Egan
Data Communications Analyst
Operations and Systems

Thomas W. Egan
Manager
Purchasing Field Office

Carol A. Elder
Consultant
Information Services

Toni Elka
Curatorial Assistant
Committee on the Visual Arts

Carla J. Fermann
Consultant
Project Athena

Nancy Ann Fierrari
Editor and Production Manager
Communications Office
Public Relations Services

Michael G. Finigan
Supervisor,
Circulation Services
Libraries

Cynthia L. Froeber
Personnel Officer
Personnel Office

Gail S. Garfield
Consultant
Information Services

Marlene Gast
Technical Writer
Administrative Systems
Development

Thomas Gately
Assistant Manager,
Maintenance,
Housing and Food Services

Linda Gelb
Librarian
Libraries

Xev Gittler
Systems Programmer
Division of Harvard-MIT Health
Sciences and Technology

A. Rae Goodell
Child Care Coordinator
Child Care Office

Regina L. Gogol
Analyst Programmer
Administrative Systems
Development

Rodney K. Goins
Associate Head Librarian
Libraries

Dianne M. Goldin
District Director
National Campaign Office

Clifford St. Julian Goodridge
Assistant to the Contract
Administrator
Office of Sponsored Programs

Paul R. Goodwin
Administrative Staff
Dean for Student Affairs

Dorothy Ann Gordon
Supervisor,
Undergraduate Records
Registrar's Office

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

David G. Graham
Route Supervisor,
Building Services
Superintendent's Office

Janice S. Green
Coordinator for Information
Input
Treasurer's Office

Barbara B. Greene
Coordinator
Office of Sponsored Programs

Caia C. Grisar
Consultant
Information Services

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

Harold C. Haizlip
Executive Director/Carnegie
Sponsored Quality Education
for Minorities Project
Dean for Student Affairs

H. Bredt Handy
Journals Editorial
and Production Manager
MIT Press

Stephanie Harriston-Diggs
Assistant Dean for Student
Affairs, Residence and Campus
Activities
Dean for Student Affairs

Rose M. Hartsgrove
Coordinator for Information
Output
Treasurer's Office

Charles E. Heitman
Sergeant
Campus Police

David M. Henry
Systems Programmer
Operations and Systems

Mary S. Hertema
Marketing and Enrollment
Administrator
Medical Department

Debora Jo Hoard
Publicity Manager
MIT Press

Steven T. Holzinger
Consultant
Property Office

Richard O. Hope
Director of Research
Dean for Student Affairs

Angela T. Horton
Administrative Assistant
Alumni Association

John F. Howard
Staff Architect/Designer
Physical Plant

Robert A. Howard
Staff Writer/Editor
Alumni Association

Faith Phipps Hruby
Staff Writer/Editor
Alumni Association

Watts S. Humphrey
Construction Supervisor
Campus Activities Complex

Anthony T. Jackson
Microcomputer Trainer
Information Services

Christina Jansen
Technology Licensing Officer
Technology Licensing Office

Richard R. Janus, Jr.
Staff Accountant
Comptroller's Accounting
Office

Ted E. Johnson
Activities Assistant,
Campus Center Complex
Campus Activities Complex

John E. Keefe
Staff Associate,
Residence and Campus
Activities
Dean for Student Affairs

Deborah Kelley
Manager of Benefits
Personnel Office

Martin J. Kelly
Staff Accountant
Comptroller's Accounting
Office

George H. Kilmarx
Engineering Projects Manager
Physical Plant

Patricia A. Knieriem
Manager, Parking and Traffic
Division
Campus Police

Karl F. Koster
Industrial Liaison Officer
Industrial Liaison Program

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

Marie-Therese Kouo
Personnel Administrator
Department of Mathematics

Mark E. Kriegsmann
Consulting Assistant
Information Services

Claude M. Lee
Senior Production Assistant
MIT Press

Mary E. Leen
Assistant Director
Office of Development Services

Loreen E. Lejeune
Electronic Publishing
Coordinator
MIT Press

Wai-Ming Li
Analyst Programmer
Office of Facilities
Management Systems

Christopher S. Linn
Admissions Counselor
Admissions Office

Alberta C. Lipson
Assistant Dean for
Undergraduate Research
Dean for Student Affairs

Suzana T. Lisanti
Senior Technical Writer
Information Services

Maria C. Lucas
Administrative Coordinator
Sloan School of Management

Elizabeth A. Lynds
Analyst Programmer
Comptroller's Accounting
Office

E-Ping Lucia Ma
Analyst Programmer
Administrative Systems
Development

Thomas Maggiacomo
Manager of Data Processing
Comptroller's Accounting
Office

Joseph T. Maguire, Jr.
Property Manager
Treasurer's Office

Eugene F. Mallove
Staff Writer/Editor
Public Relations Services

Dianne F. Maloney
Purchasing Agent
Office of Laboratory Supplies

Meg Manderson
Administrative Assistant,
Summer Session and PPST
Program
Office of the Summer Session

Susan Mannett
Assistant to the Dean for
Personnel
School of Humanities and
Social Science

John P. Mannion
Supervisor,
Mechanical Services
Physical Plant

Cathy A. Maretz
Journals Advertising
and Exhibits Manager
MIT Press

Steven P. Margossian
Advisor to Fraternity and
Independent Living Groups
Dean for Student Affairs

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

Judith E. Mason
Administrative Assistant
Sloan School of Management

James J. Mc Carthy
Senior Analyst Programmer
Comptroller's Accounting
Office

Thomas J. Mc Cormack
Analyst Programmer
Registrar's Office

Sue H. Mc Kinley
Assistant to the Bursar,
Control and Accounting
Office of the Bursar

A. Kenneth Mc Laughlin
Supervisor,
Warehouse Operations
Office of Laboratory Supplies

Donna M. Mesthene
Coordinator of MITES
School of Engineering

Ramesh Natarajan
Senior Consultant
Information Services

Steven M. Nebiolo
Analyst Programmer
Purchasing and Stores

Charles E. Neschke, III
Systems Programmer
Project Athena

Cara S. Noferi
Facilities Information Manager
Office of Facilities
Management Systems

Katherine M. Nolan
Assistant Director
Student Financial Aid Office

Lori A. Nollet
Assistant Production Manager,
Technology Review
Alumni Association

Michael J. Norton, Jr.
Lieutenant
Campus Police

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

Elizabeth M. Ogar
Fiscal Officer
Office the Vice President
and Treasurer
Vice President for Resource
Development

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

Thomas J. Owens
Data Processing Coordinator
Libraries

Michael K. Owu
Assistant Planning Officer
Planning Office

Theresa M. Pease
Associate Director of
Communications,
Resource Development
Office of Communications

Leslie C. Perelman
Assistant Dean,
Undergraduate Education Office
Office of the Provost

Irma L. Perez
Assistant Planning Officer
Planning Office

Christopher Peterson
Systems Programmer
Project Athena

Linda G. Peterson
Coordinator,
Admissions and Degree Program
Media Arts and Science Section

Lisa C. Peterson
Assistant Director,
Office of Campaign Systems

James A. Polk
Analyst Programmer
Office of Campaign Systems

Robert V. Prior
Acquisition Editor
MIT Press

Geraldine Purdy
Assistant to the Bursar - Loan
Collections
Office of the Bursar

Kenneth G. Raeburn
Systems Programmer
Project Athena

Judith Rauchwarger
Personnel Administrator,
Department of Brain and
Cognitive Sciences

Barry C. Roberts
Purchasing Agent
Office of Laboratory Supplies

Raymond E. Roberts
Sergeant
Campus Police

Maria Rodrigues
Assistant to the Director, OME
Dean for Student Affairs

Anthony Rogers
Senior Manager for Operations
Medical Department

Williams J. Rogers
Sergeant
Campus Police

Mark A. Roman
Systems Programmer
Operations and Systems

Lucille M. Rosa
Associate Head Librarian
Libraries

Heather S. Ryan
Manager for Finance and
Analysis, MIT Health Plans
Medical Department

Katherine E. Sammakia
Librarian
Libraries

Richard F. Schiavoni
Administrative Assistant
Property Office

Alan Schlingensbaum
Manager, Microcomputer Center
Information Services

Rachel S. Schneider
Analyst Programmer
Administrative Systems
Development

Barbara S. Schulman
Coordinator, Women's Studies
School of Humanities and
Social Science

Anthony G. Scivetti
Architectural CAD Assistant
Office of Facilities
Management Systems

Jolanda Scott
Staff Accountant
Comptroller's Accounting
Office

Ruth K. Seidman
Head Librarian,
Engineering and Science
Libraries

Brian S. Shannon
Assistant Transmission
Manager
Telecommunications Systems

Dorothy Shannon
Manager, Parking and Traffic
Division
Campus Police

David A. Smith
Supervisor, Circulation
Services
Libraries

William H. Smith, III
Financial Staff Assistant
Department of Biology

Virginia M. Sorenson
Assistant to the Dean
Dean for Student Affairs

Deborah A. Spence
Assistant Operations Manager
Telecommunications Systems

Anne St. Onge
Assistant to the Dean
Dean for Student Affairs

Jennifer G. Steiner
Systems Programmer
Project Athena

Fiona Stevens
Acquisition Editor
MIT Press

Betty L. Sultan
Staff Assistant to the Dean
for Student Affairs
Dean for Student Affairs

Maria Clara V. Suva Martin
Conference Coordinator
Industrial Liaison Program

David J. Tenen
Analyst Programmer
Comptroller's Accounting
Office

Gail B. Tetrault
Staff Accountant
Comptroller's Accounting
Office

Virginia Meredith Thomas
Assistant Manager,
Sustaining Fellows
and Special Events
National Campaign Office

Janice C. Thompson
Assistant to the Director
Office of Development Services

Elizabeth A. Thomson
Staff Writer/Editor
Public Relations Services

Kathleen A. Thurston
Museum Shop Coordinator
Libraries

Alan Thwaits
Editor
MIT Press

Susan R. Tibbetts
Senior Technical Writer
Information Services

Leonard C. Topa
Director of Computing
Whitaker College of Health
Sciences, Technology, and
Management

Anthony Turano, Jr.
Industrial Liaison Officer
Industrial Liaison Program

Joanne D. Turner
Staff Accountant
Comptroller's Accounting
Office

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

Mark J. Valentine
Consultant
Information Services

John F. Valleli
Personnel Administrator
Department of Brain and
Cognitive Sciences

Mark A. Vargas
Librarian
Libraries

Raul H. Varela
Utilities Engineer
Superintendent's Office

David L. Verrill
Industrial Liaison Officer
Industrial Liaison Program

Nancy B. Weiland
Marketing and Enrollment
Administrator
Medical Department

Amy J. Weiner
Computer Operations
Coordinator
Whitaker College of Health,
Sciences, Technology, and
Management

Robert E. Weirnerman
Admissions Counselor
Admissions Office

Gary T. Welsh
Senior Consultant
Information Services

Cynthia C. Westhoff
Analyst Programmer
Comptroller's Accounting
Office

Maureen C. Wolfe
Personnel Officer
Personnel Office

Leslie V. Wolff
Area Director, Alumni Fund
Alumni Association

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

Randall Wright
Industrial Liaison Officer
Industrial Liaison Program

William W. Yorston
Night Supervisor,
Campus Activities Complex
Superintendent's Office

Grant A. Young
Assistant Data Processing
Coordinator
Libraries

Karin Young
Documentation Manager
Information Services

CHANGES

Amira L. Aaron
Associate Director for
Systems and Planning
Libraries

Mark S. Ackerman
Senior Applications
Development Programmer
Project Athena

Douglas S. Alan
Software/Hardware Analyst
Department of Electrical
Engineering and Computer
Science

Jill A. Appel
Technical Supervisor
Information Services

Anne E. Armitage
Assistant Director,
Integrated Studies Program
School of Humanities
and Social Science

Gregory R. Arsenault
Senior Analyst Programmer
Fiscal Planning
and Budget Office

Paul J. Arsenault
Senior Accounting Officer
Comptroller's Accounting
Office

Katherine L. Atwood
Research Analyst
Center for Advanced
Engineering Study

Jennifer S. Banks
Librarian
Libraries

Donna M. Behmer
Associate Dean for Finance
and Administration
Sloan School of Management

Susan N. Bjorner
Librarian
Libraries

Cynthia C. Bloomquist
Associate Director
Industrial Liaison Program

Paul E. Boutin
Systems Programmer
Operations and Systems

Sarah B. Brady
Budget Officer
Fiscal Planning
and Budget Office

Harmon E. Brammer
Associate Director
Physical Plant

Elaine M. Bullen
Staff Administrator
Administrative Systems
Development

Gerald D. Burke
Technical Supervisor
Information Services

Anthony J. Canchola
Assistant Dean for Student
Affairs, OME
Dean for Student Affairs

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

Rebecca L. Chamberlain
Administrative Officer
Writing Program

Marcia V. Chapman
Assistant Director
Operations Research Center

Beverly R. Chew
Senior Consultant
Information Services

Marjorie Chryssostomidis
Librarian
Libraries

Anita R. Clamurro
Associate Head Librarian,
Engineering and Science
Libraries

Debra E. Cobb
Senior Staff Accountant
Comptroller's Accounting
Office

Vickie Edwards Conrad
Analyst Programmer
Administrative Systems
Development

Francis T. Conroy
Administrative Staff
Treasurer's Office

Paula B. Cronin
Director of Public Information
and Editor
Sloan School of Management

Frederick I. Crowley
Assistant to the Comptroller
Comptroller's Accounting
Office

Cecilia R. d'Oliveira
Director of Information
Systems
Planning and Administration
Vice President for Information
Systems

Mary Francis Daly
Administrative Assistant
Quarter Century Club

D. Hugh Darden
Associate Treasurer and
Director, Capital Gifts and
Legal Affairs
Treasurer's Office

Nina J. Davis-Millis
Librarian
Libraries

Anthony Davis
Senior Contract Administrator
Office of Sponsored Programs

Benjamin H. Davis
Senior Applications
Development Programmer
Project Athena

Elizabeth A. Derienzo
Producer, Video Course
Conference Program
Center for Advanced
Engineering Study

Constance A. Donaghey
Assistant to the Registrar
Registrar's Office

Lynne A. Dowling
Data Base Analyst
Administrative Systems
Development

Deborah L. Fairchild
Assistant Director of Finance
Fiscal Planning and Budget
Office

Anthony F. Favaloro
Contract Administrator
Office of Sponsored Programs

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

William J. Fitzgerald
Manager of Data Processing
Comptroller's Accounting
Office

John J. Ford, Jr.
Manager of Data Processing
Lincoln Fiscal Office

Carolyn Fuller
Analyst Programmer
Comptroller's Accounting
Office

Phyllis S. Galt
Technical Writer
Information Services

Diana V. Garcia-Martinez
Senior Industrial Liaison
Officer
Industrial Liaison Program

Susan M. Garvey
Analyst Programmer
Administrative Systems
Development

Kevin J. Gedrich
Manager, Production Services
Operations and Systems

Anne P. Glavin
Chief
Campus Police

Kenneth A. Goldman
Industrial Liaison Officer
Industrial Liaison Program

A. Rae Goodell
Child Care Coordinator
Child Care Office

Stephen J. Gorman
Senior Accounting Officer
Comptroller's Accounting
Office

Eduardo Grado
Associate Director of
Admissions
Admissions Office

Lois A. Graham
Assistant to the Secretary
of the Corporation
Office of the President

Sarah H. Gramenz
Librarian
Libraries

Janice S. Green
Coordinator for Information
Input
Treasurer's Office

Kathleen A. Green
Associate Head Librarian
Libraries

Cathy Cook Greene
Librarian
Libraries

Patricia K. Greer
Senior Contract Administrator
Office of Sponsored Programs

Elizabeth Jane Griffin
Executive Assistant to the
Vice President and Treasurer
Treasurer's Office

Susan E. Guralnik
Administrative Officer
Department of Earth,
Atmospheric, and Planetary
Sciences

Patricia E. Harrison
Staff Writer/Editor
Office of Communications

Donald E. Heller
Director, Administrative
Systems Development
Vice President for Information
Systems

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

Richard W. Hines
Librarian
Libraries

Gloria A. Hodgens
Manager of Young Alumni
Programs
Alumni Association

Steven T. Holzinger
Consultant
Property Office

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

Anita D. Horton
Senior Industrial Liaison
Officer
Industrial Liaison Program

John J. Hynes
Assistant to the Vice
President for Research
Office of the Provost

Arlyne A. Jackson
Associate Head Librarian
Libraries

Mary R. Jasinski
Assistant to the Registrar
Registrar's Office

Susan B. Smullin Jones
Senior Technical Writer
Information Services

Demetri A. Karageorge
Accounting Officer
Comptroller's Accounting
Office

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

Donna M. Kendall
Assistant Director
Student Financial Aid Office

Patrick M. Kenny
Analyst Programmer
Administrative Systems
Development

Katherine G. Kline
Acting Director,
List Visual Arts Center
Committee on the Visual Arts

Karen L. Kramaric
Technology Licensing Officer
Technology Licensing Office

Kathleen M. Lalor
Senior Accounting Officer
Comptroller's Accounting
Office

Ann M. Langton
Accounting Officer
Comptroller's Accounting
Office

Joanne W. Larrabee
Technical Supervisor
Information Services

John S. Lavalle
Assistant to the Comptroller
Comptroller's Accounting
Office

Virginia R. Leavy
Associate Director for
Programs and Publications
Center for Real Estate
Development

Lois B. Levine
Associate Director
Student Financial Aid Office

Mark H. Levine
Senior Systems Programmer
Project Athena

Susan M. Lewis
Staff Writer/ Editor
Alumni Association

Katharyn L. Lieben
Documentation Manager
Project Athena

Bette M. Livesey
Administrative Assistant,
VAX Resource Center
Information Services

Grace C. Locke
Administrative Assistant
Sloan School of Management

Kathryn W. Lombardi
Executive Assistant to the
President and Director of
Public Relation Services
Office of the President

Bernard R. Lougee
Senior Technical Writer
Administrative Systems
Development

Thomas A. Lynch
Construction Coordinator
Physical Plant

Lawrence E. Maguire
Director
Housing and Food Services

Anne Mahoney
Senior Staff Accountant
Comptroller's Accounting
Office

James J. Maloney
Assistant Supervisor,
Carpenter Shop
Physical Plant

Nathaniel H. Mayes, Jr.
Director of Development for
the Sloan Sloan School of
Management
Office of the Vice President
for Resource Development

Karen P. Mc Carty
Operations and
Administration Manager
Telecommunications Systems

Timothy J. Mc Govern
Area Manager
Architecture and Strategic
Technology

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

Philip M. Mc Mahon
Assistant Comptroller
Lincoln Fiscal Office

Marilyn A. Mc Millan
Director, Architecture and
Strategic Technology
Vice President for Information
Systems

Marilyn G. Mc Sweeney
Librarian
Libraries

Linda B. Merims
Senior Consultant
Project Athena

Celia W. Metcalf
Associate Director,
Design Services
Public Relations Services

Lucy V. Miller
Major Gifts Officer for
Principal Gifts
Director Major Gifts

Edward J. Moriarty
Applications Development
Programmer
Department of Electrical
Engineering and Computer
Science

Doreen Morris
Assistant to the Provost
and the Senior Vice President
Office of the Provost

Mary L. Morrissey
Director of Special Events
and the Information Center
Public Relations Services

Thomas E. Mullen
Assistant Comptroller
Comptroller's Accounting
Office

Maria S. Murphy
Assistant Director
Office of the Summer Session

Deborah D. Myrick
Facilities Coordinator,
Operations and Systems

Steven Wade Neiterman
Analyst Programmer
Architecture and Strategic
Technology

Shava Nerad
Systems Programmer
Information Services

Sandra J. Nett
Manager of Retail
and Administrative Operations
Campus Activities Complex

Karen A. Nilsson
Manager,
Graduate Housing Operations
Housing

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

Junco N. Norton
Administrative Officer
Industrial Liaison Program

Richard J. Noyes
Associate Director, CAES
and Director, Video Course
and Conference Programs
Center for Advanced
Engineering Study

Richard H. O'Connell
Senior Analyst Programmer
Alumni Association

John D. O'Sullivan
Assistant Comptroller
Comptroller's Accounting
Office

Kevin J. O'Toole
Director, VI-A Internship
Program
Department of Electrical
Engineering and Computer
Science

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

Cassandra N. Page
Manager, Sustaining Fellows
Program
National Campaign Office

Stephen M. Patterson
Staff Associate,
Undergraduate Academic Support
Dean for Student Affairs

Jo Lynne Payne
Librarian
Libraries

Barbara A. Peterson
Manager of Student Programs
Alumni Association

Muriel A. Petranic
Administrative Assistant
Office of the President

Helen L. Ploss
Associate Head Librarian
Libraries

Jan Popiel
Technical Supervisor
Architecture and Strategic
Technology

Amy L. Porter
Technology Licensing Officer
Technology Licensing Office

Ugebai M. Poweigha
Budget Officer
Fiscal Planning
and Budget Office

Kathleen A. Powers
Associate Head Librarian
Libraries

William H. Ramsey
Executive Director of Special
Programs
School of Engineering

Laxmi J. Rao
Area Manager
Office of Facilities
Management Systems

Ann B. Reilly
Assistant to the Bursar,
Information Systems
Office of the Bursar

Carol S. Robinson
Librarian
Libraries

Laura M. Robinson
Senior Industrial Liaison
Officer
Industrial Liaison Program

Eugene H. Salois
Detective
Campus Police

Michael Sampson
Senior Consultant
Administrative Systems
Development

Cristina Sanmartin
Subsidiary Rights Manager
MIT Press

Carmen F. Santos
Assistant Accounting Officer
Treasurer's Office

Bonnie J. Schaefer
Contract Administrator
Office of Sponsored Programs

Charles A. Shaw
Institute Auditor
Audit Division

John J. Shea, Jr.
Manager, Stores Operations
Office of Laboratory Supplies

Diane J. Shea
Manager, Stores
Purchasing and Administration
Office of Laboratory Supplies

Sheriefa Siers
Senior Analyst Programmer
Comptroller's Accounting
Office

Frank J. Silva, Jr.
Senior Staff Accountant
Comptroller's Accounting
Office

Michael A. Silvia
Assistant Director,
Subcontracting and Government
Relations
Purchasing and Stores

Jacqueline R. Simonis
Associate Dean, Student
Assistance Services
Dean for Student Affairs

Kathy L. Simons
Child Care Administrator
Child Care Office

Jane D. Smith
Associate Director,
Student Financial Aid Office

Merrill W. Smith
Associate Head Librarian
Libraries

David Mark Sprague
Systems Programmer
Operations and Systems

Wendy B. Stone
Manager of Systems,
Physical Plant
Superintendent's Office

Sambasivan Ssuresh
Coordinator,
Facilities Maintenance
Division of Comparative
Medicine

George S. Tarasenko
Systems Programmer
Administrative Systems
Development

Edith A. Thompson
Assistant Accounting Officer
Comptroller's Accounting
Office

Scott B. Thorne
Analyst Programmer
Architecture and Strategic
Technology

William R. Tibbs
Planning Officer
Planning Office

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

John B. Turner
Associate Dean/Graduate School
Dean of the Graduate School
Office

Marjorie L. Tyler
Administrative Assistant
Office of the Provost

Robert L. Van De Pitte
Senior Contract Administrator
Office of Sponsored Programs

Marie T. Vander Sande
Senior Industrial Liaison
Officer
Industrial Liaison Program

Mark A. Vargas
Librarian
Libraries

Maryglenn Vincens
Senior Staff Associate,
Undergraduate Academic
Support Office
Dean for Student Affairs

Lisa J. Walker
Analyst Programmer
Comptroller's Accounting
Office

Bonnie J. Walters
Assistant Dean for Student
Affairs, UASO
Dean for Student Affairs

Donna E. Webber
Associate Head Librarian
Libraries

B. Jean Weidemier
Technology Licensing Officer
Technology Licensing Office

Robert E. Weinerman
Admissions Counselor
Admissions Office

Cynthia C. Westhoff
Analyst Programmer
Comptroller's Accounting
Office

Mary E. Westlund
Video Operations Coordinator
Center for Advanced
Engineering Study

Gregory D. Whall
Manager, Office of Development
Information Management
Systems
Office of Campaign Systems

Elizabeth J. Whittaker
Associate Secretary of the
Corporation
Chairman of the Corporation

David S. Wiley
Registrar
Registrar's Office

John S. Wilson
Assistant Director of
Corporate Development
Resource Development Vice
President

Sandra Gay Yulke
Senior Industrial Liaison
Officer
Industrial Liaison Program

H. Lauren Zachmann
Staff Administrator
Media Laboratory

PROVOST

In my third report as Provost I would like to make a few observations about the year and then about some of the major issues that I see on MIT's agenda.

The year was marked by a difficult episode: the manner in which the decision was reached to close the Department of Applied Biological Sciences. The decision to close the department was based on the judgment that its primary activities could be pursued more successfully in other academic settings at MIT. I am convinced that this decision was the correct one, but the manner in which it was implemented left much to be desired. It is clear that there should have been broader faculty consultation and planning for implementation before the decision was taken. This has been characteristic of major organizational changes in the past, and we intend to see that such consultation and planning occurs in any future cases of academic reorganization.

Throughout the spring term, members of the Department's faculty worked to help resolve issues relating to colleagues' and students' careers and to the future of the educational and research programs in the applied biological sciences. With their assistance, and that of many others in the faculty and administration, arrangements were made for the faculty, graduate students, and staff to join groups of colleagues having similar and complimentary interests in other departments or academic units. These new relationships will provide opportunities to continue and strengthen the activities in these fields, notably those in biotechnology and toxicology.

Finally, I should like to note that universities must always be prepared to make major decisions that will influence their intellectual future. We should not permit the experience of the closing of the Department of Applied Biological Sciences to stop us from making the critical judgments and difficult decisions that accompany institutional renewal. Rather, we must ensure that sensible policies and procedures are in place to permit such decisions to be made in a way that is both fair and supportive of individual faculty interests and career growth.

In other areas, noteworthy accomplishments during the past year include the following:

1. The agreement reached with the Howard Hughes Medical Research Institute to support a major program in basic biomedical research at MIT.
2. The launching of the Leaders in Manufacturing Program. Jointly sponsored by the School of Engineering and the School of Management, this program is devoted to education and research on the important subjects of manufacturing and process engineering, which many view as being vital to improving industrial productivity in this country. MIT is indebted to Abraham B. Siegel and Lester C. Thurow, the former and present Deans of the School of Management and especially to Gerald L. Wilson, Dean of the School of Engineering, for conceiving this program and attracting the support necessary for its realization.
3. Continued progress in a number of aspects of undergraduate education and undergraduate life at MIT. Dean of Undergraduate Education, Margaret L.A. MacVicar, and Dean for Student Affairs, Shirley M. McBay, are continuing work with a variety of groups to reach new recommendations for consideration by the faculty, especially with regard to the freshman year. The President and I remain strongly committed to supporting the process of reappraisal of the undergraduate program at MIT.
4. The successful launching of MIT's Campaign for the future, with many faculty contributing effectively to the Campaign's success. As of June 30, 1988 over \$300 million of the campaign total of \$550 million had been raised, and I am confident that this effort, which is so vital to MIT's long-term future, will be extremely successful.
5. A complete evaluation of the mission and strategy of the School of Management, under the leadership of Dean Thurow. The results, which have the strong backing of the MIT administration, set a direction for the School of Management that is unique for American business schools. The new direction places an emphasis on technology -- a strategy designed to take advantage of the strengths of other schools at MIT.

* * *

Despite these notable achievements there remain a number of significant issues which face MIT in the coming three to five years. Several of the issues which I believe will require attention during the coming year are noted below.

1. Student Housing. Currently the Dean for Student Affairs is sponsoring a Committee to study issues surrounding undergraduate living groups. There is also the related and long-standing question of whether Residence-Orientation (RO) week, with its current emphasis on living group selection, provides the best introduction of first year students to MIT. In September, I intend to establish a committee composed of faculty, students, and staff to address the question of whether the residence selection week should be eliminated and all freshmen assigned rooms in on-campus dormitories. This would be a major change for undergraduate life at MIT and the pros and cons must be carefully addressed. With regard to graduate student housing, the continued rise in Boston area rental levels means that in order for MIT to continue to attract outstanding graduate students, it may well prove necessary to expand our efforts to provide graduate student housing. Currently plans are underway to convert some property on nearby Albany Street into housing for some 185 graduate students, but we may need even more housing on or near campus.

2. There is a compelling need to review the Institute's retirement programs. For the past year Vice President Constantine B. Simonides has been leading a group undertaking a strategic review of benefits. The retirement benefit policy of the Institute has special significance currently for the academic health of the Institute because of the relationship of retirement (broadly interpreted) to the federally mandated lifting of the retirement age for tenured faculty. I intend to devote an increasing fraction of my time to the issue of faculty retirement because I believe this to be a central issue for the continued vitality of US universities.

3. Projections of the MIT operating budget indicate a worsening deficit over the next three years. This trend should come as no surprise -- for the past several years faculty salary increases have exceeded tuition increases, there has been a continuing upward move of benefits costs, and on-campus sponsored research growth has flattened. Relief from this adverse budgetary trend cannot be anticipated until later in the Campaign or until federal support to MIT improves. What is less clear is how the Institute should best deal with this worsening financial condition. During the fall term, it is my intention to call together a small group to help formulate a strategy for dealing with this problem. Our response will not be to knick an equally small proportion out of every program in the Institute but rather to assess programmatic priorities and needs and make budgetary recommendations based on that assessment.

4. Lincoln Laboratory. For the past several years questions have been raised about the relationship between Lincoln Laboratory and MIT. In brief, there are those who ask if the original reasons that led MIT to manage Lincoln Laboratory still hold and, conversely, whether it is in the Laboratory's interest to continue to be managed by MIT. There are a number of perspectives to be taken in assessing this issue, including the interests of the nation, this university, and the Laboratory. It seems to me that it is timely to begin to undertake such a review when there is no crisis facing the relationship and when the federal administration is changing. Accordingly, it is my intention to launch such a review beginning in the spring term.

5. Affirmative Action. It is clear that MIT has not compiled an adequate record of attracting under-represented minorities and women to the faculty. This lack of success is even more discouraging when contrasted with the considerable success we have had in increasing the diversity of the undergraduate student body. Both the President and I are becoming increasingly concerned with lack of progress in this area and we shall launch some new initiatives this fall aimed at increasing the presence of minority scholars on campus. We also intend to reexamine the reasons that we have not been more successful at meeting faculty recruiting objectives for underrepresented minorities.

* * *

MIT remains a vital and exciting place for students, faculty, and staff. As a result, there are many issues that deserve our attention, especially difficult questions of resource allocation. I thank those members of the faculty and staff who have aided me in the past and who will assist in the future in dealing with the hard questions which inevitably accompany excellence.

John M. Deutch

Libraries

Among the major events and activities in the MIT Libraries during the past year were the selection of an architect and the beginning of the design for an addition to the Rotch Library of Architecture and Planning; the development and implementation of a comprehensive planning process; a serial cancellation project that will result in the reduction of the subscription base by almost 14 percent; an inordinately high number of professional staff vacancies and a corresponding increase in the level of search committee activity; receipt of a major gift for support of the expansion of the online system; and the closing of all of the Libraries' card catalogues.

The staff, at all levels, responded with a high level of enthusiasm and imagination to the challenges presented by what was clearly an unusually active year. Many of them took on additional committee and task force assignments; several librarians became participants in management teams in the Engineering and Science Libraries; throughout the system there was a strong spirit of cooperation and collegiality. The net result was a year in which considerable progress was made in a number of areas without any perceptible decrease in the quality and quantity of continuing services and activities.

Planning

A six member Planning Team was created following the recommendations emanating from the "planning to plan" retreat held in June, 1987. The Team consisted of three members of the senior administration -- the Associate Directors for Administration, Public Services, and Systems and Planning -- and three other members of Library Council -- the Head of the Acquisitions Department, the Humanities Librarian, and the Preservation and Collections Librarian. The group, chaired initially by the Associate Director for Systems and Planning, and subsequently by the Associate Director for Administration, developed a year long process that entailed, among other activities, an environmental scan, the identification of a set of organizational values, the major elements of a vision of the future for the MIT Libraries, and a set of directions and action plans for implementation over the next five years. The principal participants in the planning process were the members of Library Council -- the department heads and senior managers of the Libraries although a number of other staff participated in the work of various subgroups. During July and August of 1988, the Planning Team will be briefing all of the members of the staff about the planning process and seeking their ideas and reactions for inclusion in the actual plan, due for submission to the Institute administration in late 1988.

The environmental scan revealed a number of trends, both internal to MIT, and external, that were seen as having particular impact on the role and function of the MIT Libraries during the next five to ten years. As a research library, there will be a need to identify more precisely the needs of users and to structure, market, and deliver services responsive to these needs. There will be a greater emphasis on access to information and less of an attempt to build comprehensive collections. Newer technologies will provide faster and deeper access to information but will not substantially replace existing formats and techniques, thus increasing the overall cost of operations. This will require innovative and imaginative budgeting and fund-raising on the part of the Libraries. The availability of personal computers and campus networks will present both an opportunity and a challenge for libraries as faculty, research staff, and students become more information-literate and as their requirements for information and document delivery become more sophisticated. Within the Institute itself, there were a number of factors that could have significant impact on the Libraries. These include the growth of teaching and research programs linking the School of Engineering and the School of Management; the continuing expansion and diversity of research efforts in the life sciences; major changes in the approach being taken to humanistic and social science education as part of the undergraduate curriculum; and the decline in the size and number of independent departmental libraries and reading rooms.

The key elements of the Libraries' organizational values are: (1) a need to develop a strong focus on service; (2) concern for the well-being of the staff both in terms of personal growth and morale; (3) the improvement of communication at all levels; (4) the encouragement of creativity and risk-taking; (5) the development of greater flexibility and acceptance of change, and with that, a more pragmatic approach to the Libraries' work; (6) a need to continue to ensure the integrity of the collections.

It is anticipated that the plan, as it evolves, will have a number of important characteristics:

- a strong user service orientation.
- intelligent use of appropriate technology.

- a careful balance between access to information and acquisition of information, with appropriate differentiation by disciplinary area.
- closer attention to interdisciplinary areas of research and teaching, both in terms of collections and services.
- increased focus on the needs of undergraduates.
- aggressive marketing of the Libraries as an information resource and as a participant in the Institute's educational and research programs.
- an emphasis on the importance of the library as a place for self-education and discovery.

As the planning process moves forward, it will be necessary to maintain the sense of a single library system that has both a commonality of philosophy and mission and yet retains sufficient flexibility to respond to the particular needs of segments of the MIT community. The five year plan is visualized as a dynamic model that will continue to be analyzed, reviewed, revised, and restructured as educational, research, financial, political, and technological conditions change.

Serials

The financial burden placed upon research libraries by a decade-long escalation in the price of serials, especially those published outside the United States and/or with a scientific or technical focus, has been the subject of numerous meetings, articles, and annual reports. The comprehensive review of the MIT Libraries' serial subscriptions forecast in last year's Annual Report began early in the 1987/88 academic year. By the end of June, most of the work involved in identifying titles, consulting with faculty, and final decision-making had been accomplished. Some additional faculty review will take place during the summer with all cancellations expected to have been effected by early September.

All of the Libraries' subject specialists were deeply involved in developing lists of titles for consideration, consulting with faculty both individually and collectively, and working closely together to provide a systematic and consistent approach to the problem of reducing the serials budget base. While the final figures will not be available until the fall of 1988, the approximate results of the review indicate that the 1986/87 serials budget of \$1.54 million will be reduced by about 14 percent, or some \$210,000. About 80 percent of the dollars will come from the Engineering and Science Libraries collections. Included in this group are a number of foreign language titles as well as several bibliographical tools that are concurrently available in online form. The criteria for selection included frequency of use, current faculty/research interest, importance to the discipline, and, not inconsequentially, the recent pricing history of the title. The Humanities Library titles were concentrated in national bibliography and library science. Few titles were cancelled in architecture and planning given the relatively small portion of the budget of that library devoted to serials. The percentage of the serials budget cut in the social sciences and management was less than the system-wide total (7 percent as compared to 14 percent) but a significantly larger number of titles was affected because of the proportionally lower average price. One of constraints inherent in this project was that the average cost of scientific and technical journals is much higher than those in the social science, management, humanities, architecture and planning. Establishing a goal on the basis of number of titles was, therefore, impractical. The average price of technical and scientific titles to be cancelled is about \$300; the average for economics, political science and management is \$33. In addition, consideration had to be given to overall funding patterns, to the relative size of individual budgets, and to the range and depth of research and teaching programs.

The impact of this major cancellation program has negative and positive aspects. On the minus side is a clear reduction in the quality of the Libraries' collections, although a substantial number of titles cancelled will probably not produce much reaction. A few titles will prove to result in a real hardship for some individuals or groups of patrons and the potentiality for reinstatement of subscriptions exists. Additional funding will have to be allocated to external document delivery and the potential for overload in interlibrary borrowing is real. On the positive side of the ledger is the creation of funding for increased access to CD-ROM based services. A number of compact disc based services have either been acquired or are on order including Books in Print, Ulrich's Periodical Directory, Academic Index, Science Citation Index, and LotusOneSource CD/Corporate. Additional titles are being evaluated. A second, and perhaps equally significant outcome, is the provision of funds for new titles. The MIT Libraries have been unable, for many years, to acquire new titles except on a "cancel/order" basis in which one or more existing titles had to be cancelled in order to generate funds for a new journal. It is imperative that a research university library such as MIT have the capacity to acquire journals, especially in new and emerging fields of research. The Libraries have also been able to preserve the current level of funding for monograph purchases. This is seen as especially important in the social sciences, humanities, architecture, planning, linguistics, and music. Finally, and not insignificantly, MIT, along with many other university and college libraries, is sending a message to the publishers of scholarly journals,

primarily in the for-profit sector, and secondarily to learned societies, that there is a bottom to the "bottomless pit". The long-range solution to the problem of serial pricing, however, resides in the much more complicated intersection of research, scholarship, tenure and promotion, dissemination of information, and technology. In the short term, budget restraint in support of serials is inevitable.

Budget Outlook

The serials crisis noted above notwithstanding, the Libraries received strong support from the central administration in response to the 1988/89 budget request. Additional funding to meet inflationary pressures on the acquisition budget was provided for 1988/89 and guidelines for the 1989/90 budget were also increased. Additional funds were provided for expenses connected with the new telephone system, for additional storage at the Harvard Depository, for CD-ROM workstations and databases intended primarily for undergraduate students, and for salary equity for professional staff.

Personnel and Organizational Change

Over the past decade, the Libraries have averaged eight professional vacancies each academic year. During the past year, there were active searches for double that number with half of the positions having been filled by the end of the year in June. Two positions were made vacant by retirement and two by non-reappointment of the incumbent. The remaining turnover was the result of staff members leaving MIT for higher level positions in other academic, primarily research, libraries. Within the past ten years, three senior staff members have become directors of other Association of Research Libraries member institutions, two have become directors of other academic libraries, and over a dozen have been appointed assistant directors or department heads or heads of major branch libraries. In addition, a number of recent searches have resulted in the promotion of an internal candidate thus generating a second search. While the time committed to this process represents a major allocation of staff resources, the Libraries have benefited from an influx of new professional staff, complementing the continuing group of librarians and other specialists. Among the major appointments during the past year were Ruth Seidman, formerly director of the library at the Air Force Geophysics Laboratory at Hanscom Field, who became the first Head of the Engineering and Science Libraries, and Carol Fleishauer, who will move from chief of the Acquisitions Department at Stanford University to Associate Director for Collection Management and Technical Services at MIT.

In January 1988, the Database Maintenance Section of the Catalogue Department was reconstituted as a new, separate department under the administration of the Associate Director for Collection Management and Technical Services. As the Bibliographic Databases Services Department, this unit will be responsible for the development, quality assurance, and bibliographic integrity of all of the Libraries' databases. In an environment that is increasingly "online", the critical nature of these activities, including MIT's relationship with external agencies such as the Library of Congress and OCLC, made it particularly desirable to establish database maintenance at the departmental level.

Several other personnel/administrative changes were effected during the year:

- Thomas L. Wilding, Associate Director for Administration, was given the additional title of Senior Associate Director of Libraries. With this change, he will assume additional responsibilities for the day-to-day management of the Libraries, especially in the areas of personnel, budget, facilities management, and staff development.
- The Libraries established a program of internally funded research grants for librarian and other academic staff.
- A major change in the classification structure for librarians resulted in the creation of a third promotion step (Librarian III) for non-administrative positions.

Technology and the Libraries

Planning continued for expansion of the online system. A grant of \$100,000 from the Booth-Ferris Foundation will insure the Libraries' ability to expand the hardware and software configurations supporting the Barton system. The primary objectives of this expansion are to provide extensive access capacity both through the evolving campus network and beyond MIT; to offer limited Boolean search capability for the online catalogue; to include a full, online acquisitions system; and to provide online authority control.

The Barton system continued to serve the MIT community well during the year. The Systems Office installed a number of new features including the full implementation of electronic mail. Beginning in the summer of 1987, records for materials on order were input into the database and later during the year, records for

gifts and for monographs received on standing order were added. During the second half of the year, records for MIT these were input directly from the Institute Archives. The inclusion of in-process records has both extended the utility and value of the online database and eliminated a great deal of manual effort and a significant number of paper files. Other activities included implementation of the reserve module, loading of a two-year backlog of serial records, and establishing of electronic interfaces with the Bursar's Office, the Accounts Receivable Office, and the Registrar's Office (for student registration information.)

Space and Facilities

A landmark event during the year was the selection of the architectural firm of Schwartz/Silver to design the addition to the Rotch Library of Architecture and Planning. The selection process covered a period of several months and moved from an early list of over 30 firms to six finalists and, subsequently to the ultimate selection. The support of the Dean of the School of Architecture and Planning and of the President, Provost, and Senior Vice President, was critical in the designation of this project as among the highest priorities for MIT. A major fund-raising program has begun and application was made for matching funds from the National Endowment for the Arts. The projected date of completion of the addition and the concomitant renovation of the existing Rotch Library is the spring of 1990.

Considerable work was done during the year to improve the physical quality of Hayden basement. Following the upgrading of air conditioning on this floor, new tables and chairs were acquired along with additional stepstools. Walls and columns were painted in bright color and all of the signage was upgraded. The net result is a space much more conducive to reading and browsing.

Plans were submitted for the renovation of Dewey Library that would result in improved space for microforms and computer terminals, better reading areas, and the creation of staff offices for the librarian staff. A second proposal was submitted for additional storage space for the MIT Museum in building N51/52. One of the highest priorities for the coming year is to develop a creative plan for the technical services area in the east wing of building 14. With additional space at a premium, efforts will focus on the use of office landscaping and modern workstations.

Publications

Two new publications in the field of computer science and artificial intelligence will be issued by the distinguished firm of G.K. Hall and Company that involve the MIT Libraries. The first is a volume entitled MIT Catalog of Computer Science and Artificial Intelligence that will contain all of MIT's holdings in these fields from the earliest acquisitions through 1986. Some 15,000 titles will be in this work including all of the monographs retrospectively converted under a Title II-C grant. The second is a new annual bibliography entitled Annual Bibliographic Guide to Computer Science that will contain the yearly additions to the collections of the MIT and Stanford University libraries, recognized as the two preeminent collections among North American research libraries. The first volume in this series will cover acquisitions from September, 1986 through August, 1987.

Another new publication was an insert to The Tech on the Libraries that was designed primarily for undergraduates as an introduction to the scope and services available on the campus. The positive response generated by this four page guide does credit to the work of the Reference and Information Services Committee. It is expected that this will be an annual publication.

The Barker Engineering Library revised and reissued a series of bibliographic searching aids with the generic title Literature in Science and Technology (LIST). The series consists of: Civil Engineering, Computer Science, Electrical Engineering, Materials Science, Mechanical Engineering, Ocean Engineering, Patents, Robotics, Standards, and Transportation.

A Selection of Highlights

The following are significant items from among the many included in the annual reports of the various library departments. They illustrate the diversity of activities, the dynamic nature of research libraries, and the resourcefulness of the staff.

- The Microreproduction Laboratory installed an automated DOCUMATE IV camera that features a high speed, moving belt transport system, for both microfiche and 16mm roll film production. The camera has increased productivity by 30 percent. MRL has also implemented the use of electronic mail and telefacsimile for the ordering of photocopies and microforms.

- The Dewey Library produced, on short notice, a complete bibliography of the works of Professor Robert M. Solow, MIT's most recent Nobel laureate. The Dewey Library also initiated the use of the legal online database, LEXIS, during the past year.
- The Harvard University and MIT libraries jointly sponsored a CD-ROM fair at which various database vendors displayed and demonstrated their systems.
- Almost all of the collections in Hayden Library were shifted during the year to accommodate growth in the collections and physical changes in Science and Humanities libraries.
- 24 hour per day access to the Hayden Library building for members of the MIT community is now a standard part of the Libraries' operations.
- The Rotch Library staff input over 2,000 items from the pre-catalogued collection into the online database.
- The Computerized Literature Search Service became the principal source of online service for MIT's Technology Licensing Office involving extensive searching of patent-related files. CLSS also did searching for the MIT Commission on Industrial Productivity, the Development Office, and the Health Sciences and Technology Program.
- The Catalogue Department completed the second year of a major retrospective conversion project for MIT publications. The cataloguing of new monographs in engineering, science, and the humanities has been greatly accelerated. Backlogs of new acquisitions, especially theses and MIT reports have been virtually eliminated.
- MIT applied for membership as a CONSER (Conversion of Serials) member. Participation in this program, a national effort coordinated by the Library of Congress, will enable the MIT Libraries to provide records for new and recatalogued serials to libraries throughout the U.S.
- The database of the Research Libraries Group (RLIN) that is complementary to that of the Online Computer Library Center (OCLC) is being searched regularly for cataloguing copy for new acquisitions.
- The Acquisition Department began inputting on order records at the time of order, beginning in August, 1987.
- The space allocated to the Binding and Repair Section was renovated, painted, and reorganized, following air conditioning of the space.
- The process of identifying material to be located in the Harvard Depository (HDC) was begun.
- The Corporation Visiting Committee for the Libraries met in March. Discussions focused on the expansion of Rotch Library, long range planning, services to MIT undergraduates, and fee-based services.
- The Libraries' offerings during the 1988 Independent Activities Period included programs on New England maritime history; MIT traditions and history; rare books; online information services; research methods in the humanities, in architecture, planning, and real estate development; poetry reading; and several concerts.

Gifts

Among the thousands of items received from a large number of faculty, staff, alumni, friends, and organizations during the year, were major collections from the Arthur D. Little Company (U.S. Coast and Geodetic Survey maps); Wayne V. Andersen (contemporary art slides); Gene M. Brown (biology and chemistry Constance Browne (library of the late Secor D. Browne: aeronautics and literature); Christine Buechner (library of William W. Buechner: physics); Maurice S. Fox (biology journals); Tom Kuh (management books from the library of Edwin Kuh); Zhu Lin (slides of the history of Chinese architecture); Boris Magasanik (biochemistry and biophysics journals); Suzanne Newton (personal library of George C. Newton, Jr.: environmental and electronic engineering); Walter S. Owen (materials science and engineering); Walter A. Rosenblith (books and journals); Harry L. Tuller (physics journals). The MIT Libraries also took possession of a gift made earlier by James R. Killian, Jr., former MIT President and Chairman of the Corporation. The collection included 2,500 items among which was a significant collection of first editions of the works of George Meredith as well as a number of other examples of fine printing and limited editions.

New archival collections came from President Paul E. Gray; Professor Abraham Siegel, recently Dean of the School of Management; the Departments of Meteorology, Economics, Linguistics and Philosophy; the Committee on the Writing Requirement. Major additions were made to collections of the Dean of the School of Engineering and the Industrial Liaison Program. Important manuscript collections included the papers of Thomas S. Kuhn, Cyril Stanley Smith, Benjamin Lax, Roger de Montebello, Edwin Kuh, and Henry Houghton.

Afterword

The sincere appreciation of the Director of Libraries is due to all the members of the staff who continued to provide quality service, build and maintain the collections, and contribute to the overall progress of the organization during the past year. A special note of thanks to MIT's Provost, John M. Deutch, for his continued support and encouragement and especially for his efforts in connection with the expansion of Rotch Library.

JAY K. LUCKER

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 1987 the operating budget was \$378 million, supporting the efforts of 841 professional staff, 82% of whom hold advanced degrees.

One administrative change at the Laboratory Steering Committee level occurred during the year: Brian Sack joined the Laboratory and the Committee as Associate Head of Division 1.

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 ATC automation effort has begun at Lincoln Laboratory to help air traffic controller teams at major airports. The program is developing automation that will help terminal controllers to safely move aircraft along fuel-efficient paths while continuously achieving the full capacity of the airport in all visibility conditions. Terminal air traffic control is a large-scale team effort involving physically separated controllers managing arriving and departing aircraft that are subject to a variety of unpredictable influences. Thanks to the professional skill of the people involved, an acceptable level of ATC efficiency has been maintained in the past. However, as traffic demand out-strips the ability of the physical airport facilities to expand, the cost of ATC inefficiencies increases dramatically.

In the future, it will be necessary to achieve as close to the theoretical maximum-aircraft-handling rate as possible for extended periods of time. Thus, the FAA is making a major commitment to Lincoln Laboratory to design and field test advanced automation support for control personnel. Many of the needed surveillance, navigation, and computational tools are being procured now by the FAA. Lincoln Laboratory will develop new procedures, new automation software, centralized planning techniques, and means to enhance strategic and tactical coordination. All of these techniques will rely heavily on advanced controller-interface technology. A major simulation facility will be developed at the Laboratory to evaluate candidate automation techniques. Successful 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 will be used for a real-time operational demonstration of wind shear warning products at Denver's Stapleton Airport in 1988. If this evaluation is successful, the FAA will commence the production of 43 TDWR systems. The Laboratory assisted in the TDWR technical requirements specification development and proposal evaluation.

RADAR SURVEILLANCE TECHNOLOGY PROGRAM

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.

DISCRIMINATION TEST BED PROGRAM

For many years imaging techniques have been applied to microwave signatures of satellites and re-entry vehicles to estimate a target's size, shape, and body motion. Emphasis has previously relied upon post-mission data analysis in order to establish an intelligence base on foreign objects, to evaluate target identification procedures, and to diagnose problems in the deployment of equipment in space. In 1985, however, a real-time imaging and discrimination program began at MIT Lincoln Laboratory, sponsored by the Strategic Defense Initiative Organization (SDIO), to establish a dedicated research facility where signal and data processing techniques for BMD discrimination could be developed and evaluated. Two facilities have resulted. The Lexington Discrimination System housed permanently at Lincoln Laboratory, began operation in late 1986. The Kwajalein Discrimination System is interfaced to the Millimeter Wavelength Radar and became operational in late 1987.

This program has led to field tests at the Kwajalein Missile Range in the Marshall Islands which demonstrate the effectiveness and credibility of imaging and discrimination techniques during live missions when re-entry vehicles, decoys, and deployment hardware must be identified automatically. Additionally, the facility at Kwajalein is able to image targets of opportunity (satellites and other space objects) as appropriate or needed by a broader community of users.

This test facility provides an initial evaluation of real-time imaging and discrimination techniques, using current state-of-the-art signal and data processing technology. Experiments using this unique facility are being designed to quantify system requirements and identify the technological advances necessary for the next generation of spaced-based and terrestrial strategic defense radar systems.

ROBUST SPEECH RECOGNITION

A robust, talker-dependent Hidden Markov Model (HMM) isolated-word recognition system has been developed which achieves better than 99% word accuracy over a range of stress and noise conditions using a variety of Lincoln-developed robustness techniques, including: multi-style training, perceptually-motivated distance metrics, and adaptive noise modelling.

These robustness techniques have been recently extended to produce a robust talker-dependent HMM continuous speech recognizer (CSR), which also includes models of sub-word (i.e., phone) units, and task-specific grammars. Performance varies with vocabulary size, task perplexity (i.e., average branching factor), and environment. Better than 99% word accuracy has been achieved for: a 200-word, perplexity-14 grammar, under laboratory conditions; and a 30-word, perplexity-7 grammar for a flight simulator task, under interactive workload stress.

A real-time version of the HMM CSR system has been integrated with a real-time flight simulation of an F-15 fighter to provide interactive voice control of the aircraft, and to demonstrate and evaluate speech recognition technology for complex, high-stress/noise military operating environments. This demonstration system has been exercised by a number of military pilots. Both performance (>99% phrase recognition) and realism (aircraft model, workload stress, interaction time) have been judged to be very good.

NEURAL NETWORKS

Applications of neural networks are being pursued in the domains of speech recognition, object recognition from imagery data, and complex decision problems. In addition, several approaches to implementing neural networks in silicon are being investigated.

In the speech recognition area, multi-layer perceptrons were tested on vowel classification and digit recognition tasks. They performed better than conventional Gaussian classifiers and were roughly equivalent to k-nearest neighbor classifiers. Theoretical results demonstrated that a three-layer perceptron can form arbitrary decision regions and arbitrary nonlinear input/output mappings. A number of original examples demonstrated that a two-layer perceptron can form both disjoint and convex decision regions. Detailed simulations demonstrated the capabilities of these nets. A new hierarchical two-stage neural net classifier called a feature map classifier was developed that uses combined unsupervised and supervised training. It provided performance on a vowel classification task equivalent to that of a multi-layer perceptron but with far fewer supervised training trials (100 versus 50,000 trials). Also, preliminary promising results on a new approach to temporal decoding have been obtained using a new hybrid decoder including shunting (multiplicative) nodes and time-decay nodes.

In the implementation area, an integrated circuit comprising about 36,000 transistors has been fabricated which implements a form of self-organizing neural network, as proposed by Kohonen, which acts as a feature classifier with on-chip adaptivity. A competitive adaptation process is used whereby the connection strengths between the input stimuli and the ensemble of neural elements (which represent the state of the network) are interactively modified, such that input stimuli which are judged "similar" by the network are grouped into a common class. The network automatically determines the essential distinguishing features of each class as it is exposed to increasing numbers of inputs; that is, it "learns" from experience.

This network has been used successfully to perform the front-end input feature vector classification (vector quantization) function in an isolated word, discrete observation Hidden Markov Model speech recognizer. Overall system performance was evaluated as a function of the accuracy with which the connection strengths are represented, revealing that beyond 8 bits, the network leads to recognition performance commensurate with classical methods of feature vector classification.

RAPID PROTOTYPING TECHNOLOGY

Lincoln developed techniques for restructuring the wiring on a wafer to provide the defect avoidance necessary for wafer-scale systems are now being applied to rapid customization of integrated circuits. Starting with a supply of packaged chips containing a universal pattern of active circuits and an interconnect wiring matrix, we have demonstrated that it is possible to laser-program the connectivity so as to provide any complex logic function in a matter of minutes. The technique eliminates the need for generating three masks as well as the associated wafer processing for gate arrays, thereby reducing costs and time delays by two orders of magnitude.

Present designs use a link structure which requires no special silicon processing, can therefore be fabricated in commercial foundries, and is readily exportable to industry. Initial experiments are aimed at achieving complexity levels of more than a thousand gates and developing a CAD system which will allow a designer to input a net list and a standard cell library description. The system will automatically generate the appropriate cut-and-link file and produce a functioning chip which is automatically tested on the laser table. Preliminary experiments on some dozen test chips have proven successful and designs for 1000-gate complexity are presently being fabricated.

This technique could fundamentally change the way in which designers develop digital hardware, in many cases reducing board level designs to a single chip in a matter of hours at very low cost, and allowing an evolutionary, experimental approach to building custom circuits.

WAFER-SCALE ADAPTIVE NULLING PROCESSOR

A wafer-scale jammer nulling processor is being developed for space-based radar applications, which offers an order-of-magnitude improvement in performance over contemporary nulling systems in an ultra-compact form factor. It is designed to accommodate 64 degrees-of-freedom, with an equivalent throughput of ~2 billion arithmetic operations/sec. The algorithm is based upon the Givens voltage-domain approach, implemented with CORDIC (Coordinate Rotation Digital Computation) rotators. The architecture is a 32-stage folded, linear systolic array with bi-directional data flow to insure uniform loading of all processing elements.

Each of the 32 stages contains 3 CORDIC/memory cells, one of which does not require a working memory. A 32-stage system would comprise 96 CORDIC/memory cells, amounting to ~3 million working transistors, and is being fabricated in 2- μ m bulk CMOS restructurable VLSI technology.

MX-1 ADVANCED MULTIPROCESSOR

Lincoln is developing a powerful, shared-memory, multiple instruction-multiple data (MIMD) parallel computer for signal understanding system applications, with a specific emphasis on target recognition. The system, called MX-1, provides a flexible, high-performance integrated symbolic/numeric computing environment for rapid turnaround algorithm development and evaluation, while maintaining the essential features of high productivity-oriented AI workstation. MX-1 provides the essential tools to investigate such fundamental parallel processing issues as algorithm decomposition, process granularity, and inter-process communications.

The system in its basic configuration comprises 16 processing elements (PE), a full crossbar switch, an interface system, and a symbolic host computer, and represents 320 MFLOPS of peak throughput with 144 Mbytes of physical memory. Sixteen high-speed parallel I/O ports allow direct coupling of sensor data to the processing elements. A high-level programming language is provided based on CommonLisp with extensions to support the parallel execution of numeric procedure calls. The system can be expanded in a straightforward fashion to 32, or even 64 processing elements, and is flexible enough to serve a variety of other computing applications, including neural net simulation.

MODEL BASED SILHOUETTE RECOGNITION

An experimental system has been developed which recognizes three-dimensional objects when presented with a silhouette of the object, embedded in an image taken from an unknown viewpoint. The system performs successfully in the presence of image degradations produced by noise, and in the presence of occlusions. The system further tolerates variations of about 20% in the scale of the image.

The system determines the match of an input silhouette with candidate 3-D object models by searching a tree of interpretations of silhouette edges in terms of object model edges. Although the interpretation tree typically contains 10^{20} nodes, it can be effectively investigated with on the order of 10^4 tests through judicious pruning techniques. This "intelligent" search reduces the number of viable hypotheses to a relative handful, which are then individually tested for global consistency. The system is designed to discover all legitimate interpretations of the data in terms of the object models, and will find all equivalent orientations of a symmetric object. The recognition process currently runs in typically one second to one minute on a Symbolics 3650 workstation, depending on the problem complexity.

ADAPTIVE OPTICS TECHNOLOGY

The Lincoln Laboratory adaptive optics program comprises elements in atmospheric compensation and laser beam quality improvement.

In 1987-88 a significant milestone was achieved in the adaptive correction of a high-power chemical laser at White Sands, NM. A high-power deformable mirror was used in a servo system to sense and correct phase perturbations in the laser output beam caused by turbulence in the lasting gas mixture. A significant improvement in laser beam quality was observed.

Another significant result was achieved in a demonstration of linear amplification in a Raman cell that was pumped with a modest beam quality, high-power excimer laser. A complex wavefront low-power beam was injected into the Raman cell and faithful amplification of the input was observed. With this technique, compensation for atmospheric propagation effects can be achieved using only low-power laser amplifier.

LONG-WAVELENGTH-INFRARED SCHOTTKY-BARRIER DETECTOR TECHNOLOGY

High-performance infrared imaging for surveillance and tracking of terrestrial and space objects will require very large, extremely uniform arrays of sensitive detectors. Lincoln Laboratory has achieved significant improvements in the

performance of IrSi detectors in the long-wavelength infrared region (LWIR) from 8 to 12 μm and in the processing procedures for array fabrication. State-of-the-art Schottky-barrier arrays employ PtSi detectors, which have a cutoff wavelength of about 6 μm . Although IrSi detectors have the potential for operation at significantly longer wavelengths, the characteristics of previous devices have been poor and irreproducible because it has been difficult to prepare high-quality IrSi-Si interfaces. Reproducible fabrication of detectors with cutoff wavelengths out to 10 μm has now been accomplished by employing vacuum processing for IrSi preparation to reduce impurity effects and by utilizing reactive ion etching for IrSi patterning. The detectors have higher quantum efficiency than state-of-the-art PtSi detectors in the 3 - 5 μm wavelength band. Extension of cutoff wavelength beyond 10 μm in the LWIR and increase in quantum efficiency are expected by using a newly installed ultrahigh-vacuum system to prepare IrSi with minimal contamination. Further increase of cutoff wavelength can be achieved by doping a shallow layer of the Si substrate before silicide formation to reduce the Schottky-barrier height.

In the development of processing procedures for large-scale imaging arrays, 160 x 244 element arrays with monolithic CCD readout circuitry have been fabricated using either PtSi or IrSi detectors. A very high yield of PtSi arrays with state-of-the-art performance in terms of uniformity and sensitivity has been obtained. Testing of the IrSi arrays will be performed in the near future. The technology is being transferred to industry.

PERMEABLE BASE TRANSISTOR TECHNOLOGY

The permeable base transistor (PBT), conceived in 1978 at Lincoln Laboratory, is capable of operating at frequencies beyond 100 GHz. The PBT consists of a submicrometer-periodicity tungsten grating embedded between two electrodes in a single crystal of GaAs. Current flowing between the electrodes is controlled by the grating potential. PBTs made of GaAs and packaged in discrete hybrid circuits have demonstrated record small-signal gain greater than 15 dB from DC to 40 GHz. Power amplifiers have been constructed using these devices which have shown record power-added efficiencies of 66% at 1.3 GHz and 45% at 22 GHz. Important advances in fabrication have recently produced a yield of 75%. In addition, the periodicity of the tungsten grating in the PBT has been reduced from 320 to 240 nm to achieve higher frequency operation.

WALTER MORROW, JR.

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 five 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

Each semester MIT faculty have submitted proposals for direct financial support from Project Athena. To date, we have sponsored 125 curriculum development projects, supporting faculty time, student employees, graduate research assistants and full-time professional programmers. These faculty initiatives span 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 and junior level students fluid dynamics;
- 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 and the general laboratory interface system (called the Unkelscope). We expect a significant 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.

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. This year reports on three academic departments (Civil Engineering, Chemistry and Physics) and the School of Architecture and Planning were 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

Academic Year 1987-88 represents the first year in which the original Athena vision of a coherent system of advanced workstations distributed across the MIT campus has been fully operational. The Athena system has evolved into the campus computing environment used by the vast 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 20 members and 17 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.

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 to maintain and update the approximately 70 server computers we now operate.

Athena has recently released the authentication and name service software outside MIT for beta test. We have run it internally at MIT for well over a year and expect to make it generally available in the next six months. The high level of industry interest in this software suggests the potential for widespread adoption of these systems in commercially-supported software systems.

Athena also operates two experimental network services. One provides remote access to a relational databases. The second delivers still images from a video disk sited in the MIT Libraries to the Athena video workstations. This service is generally used along with the relational database service for browsing the rich array of visual materials stored in the libraries.

Much of the Athena-developed software was first installed in September, 1987. In the past year, 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 5000 regular users at MIT spread out over the entire campus.

As of June, 1988 Athena provided the following resources:

- sixteen public or departmental clusters for general student and faculty use, including a "electronic" classroom;
- five facilities in MIT undergraduate living groups;
- nine development clusters for use by faculty;
- four projection equipped facilities for lectures requiring presentation of computer generated materials;
- a staff area in Building E40.

These facilities have approximately 750 workstations and 70 servercomputers.

Athena use generally peaks in the last two to three weeks of each semester. In one five day period in May, 1988, over half of MIT's undergraduates used Athena at least once. The semi-annual Athena surveys show that approximately 82 percent of MIT's undergraduates used Athena computing at least once last academic year.

PLANS FOR THE FUTURE

Approximately one year ago, Athena began discussions with IBM and Digital about the need for a continuation of the project. Both sponsoring companies have agreed to a three year continuation, providing ongoing hardware, staff and maintenance support as well as substantial financial assistance to MIT. The major priorities of this additional three 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 hardware by doubling the number of Athena workstations now installed and replacing the aging server computers with new, more cost-effective equipment;
- 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.

STEVEN R. LERMAN

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 in a 33 mm bore, and pulsed fields to 68 tesla 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.

On January 1, 1988, David Litster became director of the FBNML, allowing Peter Wolff to devote more time to his increasingly active research on dilute magnetic semiconductors. Several members of the FBNML research staff have left to take faculty positions at other universities. These include Richard Frankel, Charles Rosenblatt, and Yaacov Shapira. In addition, Roshan Aggarwal has accepted a position at Lincoln Laboratory, and Robert Meservey has retired; he will continue to devote 50% of his time to thin film superconductivity research. These staff changes were the consequence of an NSF decision two years ago to eliminate funding for in-house research from the core grant. We strongly believe that in-house research is an essential component of a successful national facility, and restoring it is one of our highest priorities. The next year or so will be a difficult and uncertain period for the laboratory. We are optimistic, because a panel of eminent scientists has advised the NSF that the country must have a high field research facility and has spelled out the needed resources. The FBNML intends to bid to operate a facility that implements the panel's recommendations; at this writing we do not know if the NSF has the resources required or if the laboratory's bid will be successful.

In spite of these problems, the laboratory has an impressive list of research accomplishments during the past year. We outline some of them below.

Superconductivity

The high temperature oxide superconductors all have very high estimated critical fields at 4.2K, 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. We discuss here only the in-house research activity.

The critical field of single crystal samples of high T_c materials $YBa_2Cu_3O_7$ and $NdBa_2Cu_3O_7$ have been measured as a function of crystal orientation. The critical field along the c-axis has been measured in fields to 31.5 tesla and temperatures down to 24K.

Using spin-polarized tunneling on thin-film proximity samples, the exchange interaction between rare earth moments and conduction electrons in aluminum has been examined. A spatially localized polarization of the conduction electrons, caused by the RKKY interaction has been observed.

Progress was also made in the development of conventional superconducting materials. In the relatively near future, applications will use conventional materials and we expect that progress with them will also help in developing the newer high T_c oxide materials. Intermediate scale $Nb_3Sn(Ti)$ conductors were successfully fabricated using powder metallurgy processing. These conductors were used in small magnets which were tested at 4.2K up to 20 T in water cooled Bitter magnets. The magnets matched our earlier high performance obtained in short sample tests. Preliminary results of a new high temperature powder metallurgy process for Nb_3Al yields wires with critical current densities of 10^4 A cm^{-2} at 21.8 T. This laboratory scale process shows promise for improved performance at higher fields.

Condensed Matter Chemistry

Supramolecular iron particles in the size region where the transition from molecular to solid state behavior takes place have been investigated by a combination of high field magnetization measurements and Mössbauer spectroscopy. The research has illuminated how bulk magnetic behavior develops and will serve to guide the preparation of magnetic materials.

Short-range spin correlation effects have been observed in ^{57}Fe doped $YBa_2Cu_3O_7$ by Mössbauer spectroscopy in high external magnetic fields. Two different characteristic relaxation times have been identified which are interpreted as the consequence of one dimensional and two dimensional spin fluctuations at Cu(1) and Cu(2) sites.

A quantum mechanically mixed ground spin state has been observed for the first time in $\text{Fe}_4\text{S}_4(\text{SR})_4$ type clusters, which are the biologically active centers of ferredoxins. This result shows the importance of non-quenched angular momentum in determining the properties of the ground electronic state of polynuclear iron clusters and the extreme sensitivity of the ground state and structure to extrinsic crystalline factors.

Dilute Magnetic Semiconductors

In collaboration with Professor R. Ram-Mohan of Worcester Polytechnic Institute, the group has developed a phenomenological theory of bound magnetic polarons (BMP) in diluted magnetic semiconductors (such as $\text{Cd}_{1-x}\text{Mn}_x\text{Te}$), that correctly incorporates the effects of antiferromagnetic Mn^{2+} - Mn^{2+} interactions at large x values ($x \approx 0.2-0.5$). The exchange potential of the BMP was determined from the high field magnetization (to 150T) of CdMnTe . The resulting nonlinear Schrodinger equation was solved iteratively to determine BMP energies as a function of temperature and Mn-concentration. The calculations agree well with recent luminescence measurements of acceptor-BMP energies in CdMnTe carried out by the group. This work shows that in *random* CdMnTe alloys, the BMP energy saturates at 40 meV for $x > 0.2$. On the other hand, in *ordered* DMS, where Mn^{2+} - Mn^{2+} interactions are inhibited, a 240 meV BMP energy is predicted.

Nuclear Magnetic Resonance

Research continued in the analysis and development of advanced NMR techniques for applications in both solution phase and the solid state. A class of radio frequency pulse sequences allows arbitrary proton two-dimensional experiments in aqueous solution. The phenomena of rotational resonance and rotary resonance recoupling were explored with the aim of extracting structural information from non-oriented solids.

Low Field Laboratory

This laboratory continues to develop the use of extremely weak magnetic fields emitted by physiological processes as a diagnostic tool. Extensive magnetoencephalographic measurements have been made of several classes of epileptic subjects. Analysis indicates that it is possible to localize epileptic foci (sources) in the brain using these measurements. A computer modeling study of the effects of skull and head shape on the accuracy of source localization is under way.

Magnet Technology and Facilities Development

1. Optical Spectroscopy of Solids. This facility now supports a wide variety of magneto-optical studies. They include: exchange interactions and bound magnetic polarons in dilute magnetic semiconductors (see above); quantum confined states in two dimensional systems of GaAs and $(\text{Cd},\text{Mn})\text{Te}$ quantum wells and quantum dot semiconductors; and high T_c superconductors. Available techniques include resonant Raman scattering, photoluminescence, absorption/reflection spectroscopy, Faraday rotation, and optical pumping.
2. Pulsed Magnetic Fields. New Cu/Nb-matrix microcomposite wire-wound pulsed magnets have been fabricated. A second 0.5 in inside diameter magnet achieved 68.4 tesla at the full 100 kJ energy of our capacitor bank, demonstrating that we can reproduce the record fields in multilayer wire-wound magnets. A 60 T, 0.625 in inside diameter magnet also operated successfully at full energy.

Experiments on the quantized Hall effect and fractional quantized Hall effect have been extended to over 55 T at low temperatures using the new Cu/Nb pulsed field magnets.

3. Low Temperature Facility. This facility is built around a top loading dilution refrigerator, which is configured with a 20 T Bitter solenoid and an 8 T superconducting magnet. Development of the facility has continued during the past year. A modular system has been developed to provide different types of measurements. Experiments on samples can be changed in less than half a day, provided the experimental modules are less than 1 cm diameter. The following measurements are available:

- Basic electrical transport.
- Small sample dc magnetometer.
- In-situ rotatable platform.
- Small 15 kbar pressure clamp.
- Fiber optic access for transmission, reflection, emission studies.
- Thermal expansion and magnetostriction apparatus is under development.

4. Superconducting NMR Magnet. The superconducting magnet being developed for a 610 MHz spectrometer has been successfully tested and should be incorporated into a spectrometer by the end of 1988.
5. Hybrid Magnet. A new insert for the hybrid magnet now generates a continuous field of 31.8 T in a 33 mm bore. This may be enhanced to 35.3 T in a 2 mm gap between holmium pole pieces. The 31.8 T surpasses the fields from all other continuous field magnets and the 35 T barrier has been breached for the first time.
6. Low Temperature Thermometry. In a continuing effort to elucidate the effects of high magnetic fields on low temperature thermometers, a study of the effects of fields on platinum resistance thermometers has been carried out and published. This work should be especially valuable to programs measuring the properties of high T_c superconductors.

It was observed that bubbles of He can be magnetically trapped near the center of a Bitter magnet. This results from forces proportional to $B \cdot \partial B / \partial x$ at a threshold of $21 \text{ T}^2 \text{ cm}^{-1}$. Temperature increases of as much as several K were observed in the resulting small volumes of gas surrounding a sample under test. Thus, measurements at very high $B \cdot \partial B / \partial x$ should not depend solely on vapor pressure thermometry to assure accuracy and temperature stability.

J. DAVID LITSTER

Center for Cognitive Science

INTRODUCTION

During the academic year 1987-88, 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, by means of a committee structure, reviews all proposals 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 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.

The central facility in 20C-231 contains a Microvax II running DEC ULTRIX. The computer 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 Bldg. 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.

Over the past two years the Center's experimental facilities have been duplicated in the Department of Brain and Cognitive Sciences in Building E10 with equipment purchased with funds from the Fairchild Foundation, Project Athena, and individual NSF grants. Another Microvax II and about a dozen IBM AT or XT microcomputers are used for experimental research, as well as e-mail, simulation, statistical analysis, and manipulation of on-line databases of children's and aphasics' speech.

The 1987-88 year has shown continued progress in the development of the Center Laboratory. A changeover to inexpensive but powerful microcomputers, and development of the experiment control software, have been completed. As a result, the long-anticipated weaning of human subjects research from the Sloan Foundation grant to renewable funding sources is virtually complete, and experimental research is now almost fully supported by funds from within the Department of Brain and Cognitive Sciences. This is possible because of economies of scale that result from having a single programming and management staff based at the Center but serving both Linguistic and Philosophy and Brain and Cognitive Sciences Communities.

Among the specific accomplishments during the past year are the following. The experimental control software has been expanded and enhanced with new features, the most notable of which is the ability to display animation sequences of graphic images created either from a 3D solid modeling program or from the popular Macintosh MacDraw program. A Macintosh II is currently being setup as a graphics development station. Several new 80286-based computers for experimental stations have been acquired. Three Sun Workstations and a Sun Fileserver are being installed for the Parsing Project (see below).

RESEARCH

The Parsing Project

A major new research initiative has come about through a grant from the Kapor Family Foundation to the Center for support of a principle-based parsing project. The primary goal of the Parsing Project is to develop a general purpose parser which can be adapted from one language to another in a relatively simple and straightforward fashion. The Project, under the leadership of Professor Robert Berwick of the Department of Electrical Engineering and Computer Science, will support the creation of a parsing laboratory within the Center Laboratory. Placing the Parsing Project in close proximity to the other laboratory facilities will provide a workplace in which graduate students in linguistics as well as computer science can work together on problems of common interest.

During the first year of the Parsing Project a seminar, alternating with the already-established Lexicon Project, has brought speakers involved in parsing strategies to the Center to present and discuss their work. A volume of papers is currently in preparation which will present the work of these visitors and serve as a starting point for parsing research in the Project.

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 1987-88 the Center hosted seven postdoctoral fellows: Five in linguistics, one in philosophy and one in visuospatial cognition. The Center also sponsored five visiting scientists: one in language acquisition and four in linguistics.

The Affiliate Program

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

The Member Program

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

Seminars and Colloquia

During the 1987-88 academic year the Center continued to support three 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 North east. Last year in particular over 750 members of the community attended a total of 9 seminars. In addition, the Lexicon Project in conjunction with the Parsing Project conducted a year long weekly seminar. Approximately 22 talks were given last year.

The Occasional Paper Program

The Center for Cognitive Science sponsors a series of Occasional Papers. The papers attempt 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, twenty-three papers have been published.

Publications

The Center for Cognitive Science has supported a variety of publications by making its resources available to visiting scientists, postdoctoral fellows, predoctoral fellows, and to affiliated faculty. As of the end of the academic year 1987-88, a total of 18 books and 185 articles had been published as a result of Center support.

SAMUEL JAY KEYSER

Center for Materials Science and Engineering

The Center for Materials Science and Engineering (CMSE) was founded in 1960 for the study of the structure and properties of materials. Currently, major funding for the Center is provided through the Materials Research laboratory program of the National Science Foundation (NSF). The Center operates major research facilities which provide state of the art instrumentation and the expertise of professional staff to foster research projects of the materials community at MIT. We also provide seed funding for a small number of exciting projects for faculty seeking to develop new ideas, and we fund collaborative research on major problems in materials science. Last year we supported research in five major thrust areas, and provided seed funding for 23 research projects.

During the year just passed, we prepared a competitive renewal proposal for our NSF support. As part of this process, we assessed the success of our thrust area research, and decided to discontinue support for the work on defects in semiconductors. Research was proposed in six thrust areas. The NSF budget, especially for materials research, has been insufficient for some years; when an anticipated 17% increase did not materialize last year cuts had to be made in the MRL program. Consequently, one of our new thrust areas - processing of artificially structured thin films - was not funded. It is a strong program, and we intend to seek supplemental funds for it this year.

Development of our central facilities to support materials research at MIT continued. The facility we operate jointly with the Harvard University MRL on characterization and analysis of surfaces became operational. Capabilities include Rutherford back scattering, x-ray photoemission spectroscopy, and Auger electron spectroscopy. Equipment for secondary ion mass spectroscopy will arrive very soon. During the past year our x-ray scattering spectrometers at the Brookhaven Laboratory National Synchrotron Light Source were not working, as the storage ring was shut down for upgrade. We used the opportunity to build a third spectrometer, for X-ray scattering at 16 keV, on our beam line. We expect to resume operation with the third spectrometer in the summer of 1988. The crystal physics and optoelectronics facility has been reorganized into two central facilities. One is primarily concerned with growth of crystals, and the other with optical characterization & related services; this seemed to be wise in view of the increased demands on the crystal growth facility for new superconducting materials.

Some changes in CMSE staff occurred over the past year. Susan Carr, administrative assistant, took other employment outside MIT. Virginia Esau has been hired as fiscal administrator and Brian Tavares as administrative assistant. David Litster resigned as director of the laboratory on June 30, to become director of the Francis Bitter National Magnet Laboratory. The new CMSE director will be Bernhardt Wuensch.

Below, we briefly outline the research activities of our five thrust areas during the past year. The names and departmental affiliation of the individual researchers are given at the end of each section.

Transition Metal Oxides

This is a new thrust area stimulated by the discovery of superconductivity at relatively high temperatures in oxides of copper. When high T_c superconductivity was first discovered, the majority of the scientific community believed that the source of the necessary pairing of the charge carriers was, as in conventional superconductivity, the electron phonon interaction. Experiments in this thrust area, using single crystals grown in the crystal growth central facility, have radically altered this view.

The experiments include neutron scattering at the Brookhaven High Flux Beam Reactor, and conductivity, magnetoresistance, and magnetization studies in CMSE and at the Francis Bitter National Magnet Laboratory. Study of the tetragonal to orthorhombic phase transition in La_2CuO_4 showed that, even though it is a beautiful example of a soft-mode transition, the soft mode is not one that can provide strong electron phonon coupling.

The magnetic experiments revealed spectacular behavior. Experiments on pure La_2CuO_4 showed it to be a paradigm for the spin $\frac{1}{2}$ Heisenberg Hamiltonian. In the paramagnetic phase the length of the antiferromagnetic correlations grows rapidly as the temperature is decreased, and because the antiferromagnetic exchange energy is so large, $\sim 0.1\text{eV}$, the length is large, $\sim 200\text{\AA}$ at room temperature. Such a large exchange is necessary for a mechanism for high temperature superconductivity. If the

system were truly 2-dimensional, magnetic order would only be established at zero temperature. However, the antiferromagnetic state occurs at 200 - 300 K because of weak interlayer coupling and the unusually large correlation length in the paramagnetic phase.

An investigation of $\text{La}_{2-x}\text{Sr}_x\text{CuO}_4$, which is a superconductor when the density of current-carrying holes induced by Sr doping is sufficiently large ($x > 0.05$). Magnetoresistance studies of undoped material revealed a very strong coupling between the carriers and the magnetism. This was also revealed in neutron scattering experiments which showed the holes disrupt the phase coherence of the antiferromagnetic correlations while leaving the magnitude unchanged. Any theory of superconductivity in these materials must take into account that the system is composed of a concentrated rapidly fluctuating spin system strongly coupled to the carriers. The most straightforward conclusion is that the pairing for superconductivity is magnetic in origin, which most of the condensed-matter physics community now accepts.

From these studies, members of the group also produced a theoretical model in which magnetic frustration induces pairing of holes. They then used a mean field solution to their model to predict correctly the dependence of the superconducting transition temperature on hole concentration. The model is not yet universally accepted, but it has created a degree of excitement.

Faculty/Department: Professors R.J. Birgeneau, J. Graybeal, M. Kastner, P.A. Lee (Physics), M.S. Dresselhaus, T.P. Orlando (Electrical Engineering and Computer Science), Y-M Chiang, D. Rudman, H. Tuller, J. Vander Sande, G. Yurek (Materials Science and Engineering), A. Aharony (visitor to CMSE), and H. Jentsen (Principal Research Scientist, CMSE).

Phases and Phase Transitions

This group has continued to use a variety of approaches to elucidate the universal behavior of phase changes in condensed matter.

Experiments using high resolution x-ray scattering and light scattering to study the structure of free standing liquid crystal films have been extended to very thin films in order to study the crossover from three to two dimensional behavior. Beam time at storage ring sources has been essentially unavailable during the past year, but the group has been able to show that a sample 22 molecules thick shows two dimensional behavior.

Progress in developing the theoretical and experimental tools to understand the structure of micelles, microemulsions, and colloids has been substantial. This has largely been due to the combining the results of several different experimental probes in order to test the theoretical models. Combined neutron and light scattering studies of the didodecyl-dimethyl-ammonium bromide, hexane, and water microemulsion system have revealed an unexpectedly rich variety of behavior in the region of the phase diagram which is largely hexane. They represent the most thorough study yet of the microstructure of a microemulsion system.

Faculty/Department: Professors C. Garland (Chemistry), G. Benedek, A.N. Berker, R. Birgeneau, T. Greytak, J.D. Litster, T. Tanaka (Physics), S-H. Chen (Nuclear Engineering), and A. Aharony (visitor to CMSE).

Synthesis and Properties of Novel Polymers

The novel synthesis of polymers using transition metal based catalysts has been the goal of several members of this thrust area. Catalysts, based on W, Ta, and Mo organometallic chemistry, which attack carbon-carbon double (or triple) bonds only in cyclic molecules, have been used to prepare, via a ring-opening metathesis reaction, "living" polymer systems. The catalyst does not attack the double or triple bonds in the resulting polymer, making this an extremely clean reaction so that branching and cross linking do not occur. Recently preparations are polymers based on cyclopentene and norbornene, and block copolymers of these two. Films of these have been made and the properties are being characterized. The rates of polymerization and the lack of side reactions are such that extremely low polydispersity for the resulting polymers is found. This new chemistry opens up many new possibilities in polymer synthesis. Efforts are now underway to synthesize polyacetylenes and polydiacetylenes.

In addition the controlled modification of polymer morphology has been used to produce a high density of energy absorbing centers, thereby making the polymer extremely tough. Currently, the varied inelastic behavior in semicrystalline polymers is being studied to achieve even higher toughness. Also, the deformation mechanisms in both crystalline and amorphous phases are being studied.

Faculty/Department: Professors R. Schrock, R. Silbey, M. Wrighton (Chemistry), R. Cohen, U. Suter (Chemical Engineering), and A. Argon (Mechanical Engineering).

Deformation and Fracture of High Temperature Alloys

The goal of this thrust area is to advance basic materials science by obtaining a sound understanding of the mechanistic basis for the deformation and fracture behavior of metallic alloys at high temperature, as well as to develop mechanism-based laws for the rate of deformation and damage development under various conditions. This basic understanding can be used to extrapolate empirical testing results to different operating conditions and also provide a way to predict remaining life and current state of damage in parts with an uncertain history.

In a pioneering study that has combined the expertise of much of the thrust area, the rates and mechanisms of damage were studied in protective aluminide coatings on γ - γ' single crystalline substrates subjected to realistic conditions of thermal cycling. This has shown the essential effect of strain ranges on degradation by surface roughening. Other achievements include the development of state variable based constitutive laws for primary creep and creep transients in nickel derived from experimental studies on polycrystals and single crystals as well as constitutive laws for time dependent deformation at high homologous temperatures, derived from experiments on single crystalline oxide dispersion strengthened ferrous alloys, and demonstrating that the creep resistance in γ - γ' alloys derives from the severe restrictions of plasticity in very narrow, sub-micron sized γ gaps.

The group has also broadened its interests to include the study of aluminide intermetallic compounds.

Faculty/Department: Professor S. Allen, N. Grant, R. Pelloux (Materials Science and Engineering), A. Argon, L. Anand, F. McClintock, and D. Parks (Mechanical Engineering).

Innovations in Steel Technology

This group seeks to provide the scientific basis of a new steel technology aimed at specific property objectives that are important to industry. The Harvard University MRL, and a group at Brown University are other university participants in the program. The Army Materials Technology Laboratory and Los Alamos National Laboratory also participate in the program, as do Bethlehem Steel, Carpenter Steel Corp., LTV Steel, and General Motors.

The group has made progress in developing ultrahigh-strength steels. These are the materials used for critical applications in, for example, aircraft landing gear and helicopter rotor hubs. Existing steels have an ultimate tensile strength around 300 kilopounds per square inch (kpsi), and toughness of 55 ksi in $\frac{1}{2}$. However they have a serious drawback because of stress corrosion; the hydrogen ions available in a humid atmosphere will lower the toughness to 10 ksi in $\frac{1}{2}$. Helicopter rotors require a toughness of \sim 20 ksi in $\frac{1}{2}$, and there have been several recent catastrophic failures which caused grounding of army helicopters for some time. These, and related failures, prompted an article on "killer steels" about a year ago in the "Wall Street Journal".

One of the goals of the group has been to understand the microstructural and grain-boundary chemistry changes that could be made to improve the properties of these steels. By designing a microstructure that would resist fracture, while also addressing the problems of grain-boundary chemistry, they produced dispersion containing rare-earth oxy-metalloid compounds with hardenability enhancement by molybdenum. Sulphur and phosphorus, which normally embrittle grain boundaries, were "gettered" into stable dispersed particles which significantly increased the resistance to stress corrosion cracking.

The necessary grain size and uniformity of the steel were controlled by using rapid solidification techniques developed earlier at MIT. Measurements on preliminary samples show ultimate tensile strength of 300-320 ksi and toughness of 60 ksi in $\frac{1}{2}$. More importantly, the toughness in a humid atmosphere is in the 20-40 ksi in $\frac{1}{2}$ range. The next generation samples of the newly designed steel are expected to show even greater improvement. These first results indicate promise in using basic scientific knowledge to design steels for the desired properties, and should pave the way to a considerable improvement over more empirical approaches.

Dr. Olson, who has been the key participant in the group, has accepted a faculty position at Northwestern University. We expect that leadership of this effort will move with him to the Northwestern MRL during the coming year.

Faculty/Department: Professors S. Allen, M. Cohen, M. Flemings, G. Olson, and J. Vander Sande (Materials Science and Engineering), G. Olson (Senior Research Scientist, Materials Science and Engineering), and A. Garratt-Reed (Principal Research Scientist, CMSE).

J. DAVID LITSTER

Division of Comparative Medicine

The City Council of Cambridge has continued as a focus for the controversy regarding animal use in biomedical research. The Mayor of Cambridge has commissioned an external review committee to study the use of animals in biomedical research in Cambridge. It consists of a member of the scientific community, Dr. John Moses, Chairman of the Animal Care and Use Committee at MIT; a member designated by the animal rights community, attorney Steven Wise, Animal Legal Defense Fund; and a veterinarian, Dr. Stuart Wiles, who specializes in small animals, and is a resident of Cambridge. This Blue Ribbon Committee was created by unanimous vote of Cambridge City Council on September 21, 1987. The ordered objective of the Committee, among others, "is to determine whether or not adequate standards for care of laboratory animals exist in Cambridge and whether or not abuse of laboratory animals occurs." Other considerations in viewing laboratories using animals for biomedical research in the City of Cambridge include review of current sanitary conditions and internal monitoring procedures of individual laboratories, as well as review of current standards set by NIH, USDA, Animal Rescue League, and the Massachusetts Society for the Prevention of Cruelty to Animals. The Blue Ribbon Committee has reviewed different facets of the Animal Care and Use Program at MIT three times in 1988. The Report of the Blue Ribbon Committee is anticipated to be made public sometime in the early fall of 1988. The Animal Care and Use Program, in addition to the Blue Ribbon Committee review, continues to be reviewed by other outside agencies. In 1987, the Animal Care and Use Program at MIT was reviewed by the AAALAC accreditation association and we are pleased to announce that MIT continues to be fully accredited. MIT received commendations regarding our Animal Care and Use Program in the letter received from this peer review organization.

Daily census of laboratory animals has increased slightly over the last fiscal year. During the last year, the Division has concentrated on augmenting the surgical activities at the Institute, which involve laboratory animals. As such, the Surgical Resource Unit is now staffed by a full time veterinarian with training and expertise in anesthesiology and surgery. He is assisted by a veterinary surgical nurse. In the next year, the Division is also planning to take an active role in development of a transgenic mouse colony to be used by members of the Institute, specifically faculty members in the Department of Biology. The Division will also be assisting in the management of a breeding colony of Watanabe rabbits to be used in cardiovascular research. Over 100 PI's involved in animal research utilize the animal resource facilities under the direction of DCM. This activity corresponds to over 480 active protocols under review by the Animal Care and Use Committee. During FY87, the projects for biomedical research at MIT, which require animals for the conduct of the research, totalled \$18 million. This represents 175 grants from NIH and other Federal Agencies utilizing animals for research projects. In addition, during the last fiscal year, DCM submitted a grant to NIH for equipment and minor renovations of its animal facilities. This grant is expected to be funded in July 1, 1988. It will be used to upgrade cage washing facilities, and purchase new animal caging.

For the past two years, the Division has used an integrated software program written exclusively for animal facility management. The system provides cost accounting calculations for per diem setting, tabulates monthly census and billing reports, integrates animal purchasing and protocol review, and generates reports required by State and Federal legislation regarding animal care and use. Future modifications to the program include a bar code method for collecting census information from cage cards which will make it possible to update census activity on a daily basis. This procedural enhancement will enable investigators to accurately monitor animal populations by sight and by project resulting in a more financially prudent management of the animal component of their grant support. The computerization of the Diagnostic Laboratory has been approved and DCM has entered into a formal contract with General Computer Systems, Inc. This software program will eliminate redundant paper work generated by the Diagnostic Laboratory and administrative staff. The ability to log in laboratory samples as they are received and automatically produce a charge for billing purposes will expedite the accounting process necessitated by the service component of the Diagnostic Laboratory.

The Diagnostic Laboratory, in addition to providing diagnostic, and some research support to the MIT research community, continues to provide a diagnostic resource to the general biomedical community, which encompasses thirty Boston area universities, hospitals, and research institutions. The Diagnostic and Investigative Laboratory in our Division also continues to provide valuable functions, such as the study of unusual animal diseases that occur infrequently, development of new animal models for the study of human disease, and support of systematic and sophisticated studies to discover new information on disease processes and their etiology. Other functions include, cataloging of histological preparations, kodachromes, and photographs for research and training in laboratory animal science and comparative medicine.

We are happy to announce that the NIH Program for post-doctoral training of laboratory animal medicine veterinarians has been funded. The NIH Training Grant is for five years and is expected to sponsor six trainees by the third year of the grant. Only three decades have elapsed since the specialty of laboratory animal medicine was formally recognized. Laboratory animal medicine could not have evolved and flourished unless the scientific community realized the importance of understanding laboratory animal biology and diseases, the critical role of environmental conditions, and the ethical need to humanely maintain and use animals.

Laboratory animal medicine specialists balance their efforts in collaborative and independent research with clinical services and teaching. This interplay of service and research offers exciting challenges and opportunities for veterinarians. In a recent National Academy of Sciences report entitled, "Specialized Veterinary Manpower Needs Through 1990" the effect of federal legislation on supply and demand of veterinary specialties was examined. The committee surveyed current legislation and regulations pertinent to the use of biomedical manpower and selected those in which veterinarians are either specifically required or frequently needed. Laboratory animal science, pathology, and toxicology were most often cited as biomedical disciplines for which veterinarians were in high demand. Of the service responsibilities, animal welfare and health care were believed most needed; clearly the laboratory animal veterinarian can fulfill these criteria. The demand for laboratory animal medicine specialists has been impacted directly by recent legislative and regulatory developments. Unfortunately the number of ACLAM Diplomates is not increasing to meet the demands. Our NIH Training Grant is directed toward helping resolve the critical shortage of veterinarians trained in laboratory animal medicine, and is dedicated to providing the strong foundation in research training needed for a career in the biomedical sciences. In addition to seven post-doctoral trainees now in the Program, the Division continues to accept summer veterinary students, as well as one to three UROP students per semester.

Members of the Division are now involved as PI's, or CoPI's in 12 NIH, NCI or other federal or industrial supported research activities. An additional 2 grants are pending review. The major thrust of our research continues to be in the area of gastrointestinal disease. During the past year, the Division has published one book, 3 chapters, 13 papers, and 10 abstracts; 11 papers are currently in press.

JAMES G. FOX, DVM

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 among energy, the economy, and society?

The total volume of Energy Laboratory research during FY88 is estimated at \$10.5 million compared to \$11.8 million in FY87. The decline was largely anticipated since some programs ended and others foresaw reduced funding from sponsors. Thus the Energy Laboratory program on advanced energy materials was terminated and its residual work was transferred to a more appropriate home in the Materials Processing Center. Funds were cut most for programs on transportation propulsion and on synthetic fuels, but increased somewhat for programs on health effects and on electric power systems and technology.

Our sponsorship remains highly diversified with about half of fiscal 1988 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 17 academic departments (plus 5 other MIT units) participated in Energy Laboratory projects during the year; no one department accounted for more than 30 percent of our volume. That diversity helps to maintain the multidisciplinary character of research we seek, and that academic participation helps to weave our activities as closely as possible into the educational fabric at MIT.

In March, the Center for Energy Policy Research conducted a two-day workshop on "New Methods for Project and Contract Evaluation". During the workshop, both faculty and industrial associates of the Center described their work on extending modern financial techniques for the analysis of new capital investments and contracts.

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 three categories:

Health Effects of Combustion

- Hazardous emissions: what are they?
- Cleaning up residential oil burners
- Fluidized bed combustors: why are they clean?
- Coal burning: reducing the health effects
- Formation of sulfates and acid in flue gases

Energy Engineering

- Improving arc welding
- Using electronics to simulate nuclear plants
- Understanding plasma reactors
- Cracks and stress: predicting structural failure

Other

- Electrical injury: understanding the body's response
- Contaminated groundwater: fast on-site analysis
- Identifying sources of groundwater contamination
- Evaluating investment opportunities in an uncertain future
- Scaling up the fluidized bed combustor
- New device for grinding coal

Information on all the projects active in the Laboratory during fiscal 1988 may be obtained from the report entitled Project Summaries, July 1, 1987 - June 30, 1988. 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 improvement in technical products and processes. (Professor Kent F. Hansen, Program Director)

The Combustion Research Facilities program emphasizes parallel modeling and experimental investigation of combustion processes of gaseous, liquid, and solid fuels in both steady and unsteady operation. A special feature of the experimental studies is that fundamental flame data are obtained in large-scale pilot plant combustors in which the combustion-heat transfer processes closely simulate industrial practice. (Professor Janos M. Beér, Scientific Director)

Research in the High-Temperature Reactions and Health Effects program concentrates on the oxidation and pyrolysis of fuels and on techniques for controlling emissions from these processes. Studies of the formation of mutagens in hydrocarbon combustion involve a team effort among engineering, analytical chemistry, and biological sciences. (Professor John P. Longwell, Program Director; Dr. William A. Peters, Program Manager)

The Synthetic Fuels Center focuses on research on conversion of primary energy resources to liquid and gaseous fuels. Energy companies cooperate to support and offer guidance to the program. Current projects cover a broad range of activities—investigating the comminution of energy minerals, dissociative adsorption of small molecules, coal pyrolysis, and gas desulfurization. (Dr. Malcolm A. Weiss, Director)

The Transportation Propulsion program conducts research on both improving existing engines and developing new concepts. Activities are based in the Sloan Automotive Laboratory and include fundamental and applied research relevant to internal combustion engines, work on alternative propulsion concepts, and policy and technology studies. (Professor John B. Heywood, Program Director; Dr. Victor W. Wong, Program Manager)

The Energy Markets, Pricing, and Regulation program conducts research the interaction between energy markets and the macroeconomy and reviews and evaluates important energy market and environmental policy analysis models. Current research is directed to developing and implementing a model of energy and economy interactions for Egypt and to evaluating the Environmental Protection Agency's Advanced Utility Simulation Model—a large-scale computer model used to analyze national air quality policies. (Mr. David O. Wood, Program Director)

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 noncorporate interest groups. These Associates 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)

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, impacts of acid rain, and local effects of air emissions. (Professor James A. Fay, 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 18 utilities; 12 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 studies of the transfer and accumulation of moisture in structures, air circulation in interiors, new envelope materials, and aging characteristics of closed-cell foam insulation. (Professor Leon R. Glicksman, Program Director)

The Center for Innovative Mining Systems is a joint program with Pennsylvania State University. It is directed toward coal mining and emphasizes the development of simplified systems suitable for remote control, thereby removing miners from regions of high risk. (Professor Carl R. Peterson, Director)

PUBLICATIONS

During the past year, Energy Laboratory research resulted in 26 technical reports and working papers, and about 123 other publications (journal articles, workshop and conference presentations, etc.). Energy Laboratory Headquarters (E40-455, x 3400) has available a complete list of reports, working papers, and other publications, as well as copies of Project Summaries and e-lab.

MALCOLM A. WEISS

Harvard-MIT Division of Health Sciences and Technology

INTRODUCTION

The HST Division opens the enormous educational resources of both MIT and Harvard to highly qualified students who seek careers at the interface of science and engineering with medicine. The MD curriculum is designed to educate physicians with a deep and quantitative understanding of the underlying science of medicine. The PhD programs combine rigorous scientific or engineering graduate training with an in-depth exposure to the biomedical sciences and clinical medicine. Both programs seek to prepare students for leadership roles in medicine and biomedical science. A second key objective of HST is to catalyze the development of interinstitutional research programs. The Division brings together multidisciplinary teams of physicians, engineers, and scientists in programs which span the range from fundamental scientific research to applied research and development. Both in education and in research HST functions as "mortar" to bring together existing and complementary expertise at the two universities.

ADMINISTRATION

The HST Advisory Committee was formally constituted this year. This visiting committee is made up of sixteen outside consultants who are leading scientists, engineers, physicians, educators, and executives in private industry and government. The Committee was formed to evaluate, stimulate, and influence the educational and research activities of the Division, reporting to the Dean of Harvard Medical School and the Provost of MIT.

Under the leadership of Dr. Richard Johns, Professor and Director of the Biomedical Engineering Department at Johns Hopkins University, the Advisory Committee visited HST in March, and focussed its attention primarily on education. We were pleased that the Committee found the programs to be "strong and of high quality", and that they were meeting HST's primary objective: "to prepare students for leadership roles in medicine and biomedical sciences." Committee members stimulated us with several important suggestions designed to strengthen the Division. They felt that stronger contributions to HST's teaching should come from faculty in the modern biological sciences. They suggested broadening the MEMP program to include tracks to prepare engineers and physicists to address important technological problems in fundamental biomedical research (biology, biophysics, biotechnology, etc.). They also suggested strengthening our educational efforts in biomedical imaging technology and science, speech and hearing science, and clinical neurosciences. The Committee urged us to recruit more vigorously from undergraduate populations away from the local area. The full report will be carefully studied by our administration and Joint Faculty Committee over the forthcoming year.

New computer facilities were made available to HST students and faculty during the year. A departmental ATHENA cluster was completed in the Whitaker College building, which provides access to all ATHENA capabilities. A second computing facility was established at Harvard Medical School, which gives students access to word processing, HMS teaching programs, and National Library of Medicine bibliographic searches. Finally, an electronic mail system was implemented to couple HST personnel to the MIT network, Internet, and also to the Harvard Medical School electronic mail system.

Superb new space for HST has been created at the Harvard Medical School in the Medical Education Center on Longwood Avenue. These facilities were occupied in September and provide classrooms, laboratories, student study areas, computing resources, and administrative space for the HST/MD curriculum office, and that of the Chairman of the Board of Tutors and Advisors.

ACADEMIC PROGRAMS

A total of 195 graduate students were enrolled in HST degree programs during the past academic year: 150 were MD candidates, of whom 76 were simultaneously pursuing PhD degrees (40 at MIT and 36 at Harvard). There were 45 students enrolled in the doctoral program in Medical Engineering and Medical Physics.

Twenty-six HST students received the MD degree in June. Eleven of these also received PhD degrees: seven from Harvard departments, and four from MIT. Two students received PhD degrees in Medical Engineering or Medical Physics.

Next fall a total of 30 new MD candidates and ten new MEMP students will join the Division, bringing total enrollment to about 207.

Surveys were completed this year to identify the career paths of HST graduates. Dr. Irving M. London mailed questionnaires to the 246 alumni of the MD curriculum from 1975 to 1984. Seventy percent (172)

responded. Of the 134 respondents who had completed their training, an impressive 80 percent hold academic appointments. The data showed that 64 (26 percent) of the graduates had also earned PhD degrees.

As of January 1988, 24 individuals had earned the PhD degree in Medical Engineering or Medical Physics. Of these 13 also obtained the MD degree. Virtually all of the MEMP graduates are presently employed in academic or research positions. Six are faculty members in engineering or physical science departments in universities. Nine are faculty members associated with teaching hospitals or at medical research foundations. The remainder are in training status as physicians or postdoctoral fellows.

The HST doctoral program in Applied Biology in Medicine, launched last year in collaboration with the Department of Applied Biological Sciences, was cancelled following dissolution of the ABS Department.

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 in academic medicine to engage in research under faculty supervision throughout their medical studies. The availability of funded Research Assistantships 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 47 HST/MD students were RAs, and during the spring term 41 students participated in the program. In general, about 40 percent of the students work with MIT-based faculty, and the remainder work in the teaching hospitals or at HMS.

The HST FORUM was established as an annual event which celebrates the significance of student research activities in the Division. The first HST FORUM was held in October, and centered on student research presentations delivered in platform format in the auditorium of the Whitehead Institute, or in poster format in the Whitaker College building. Research topics presented covered a wide range of disciplines including biology, biomechanics, chemical engineering, chemistry, electrical engineering, genetics, imaging, mechanical engineering, physics, and physiology. Forty presentations were received by an enthusiastic audience of students, faculty, and alumni. The scientific meeting was followed by a dinner-dance lasting late into the night.

A new Master's Degree in Health Science and Technology for HST/MD students was established this year by vote of both the MIT faculty and the Faculty Council at HMS. The degree requires a substantial commitment to research documented in a thesis, and additional course work. The program is designed to provide academic structure and oversight to the enhanced research component of the HST/MD curriculum, and would normally require an additional year or more of study beyond the four-year MD program. The degree may be awarded by MIT or by HMS depending on the location of the student's research. The program will be formally instituted in September.

HST was the recipient of a \$1.5 million grant from the Johnson & Johnson Company over a period of five years. Three hundred thousand dollars will be received each year: \$100,000 for student fellowship support, and \$200,000 for HST-related faculty research. The grant program is administered by an HST faculty committee. This year a total of 44 applications were received from MIT and Harvard faculty members. Fourteen awards were made for projects which include HST student RA's. The program promises to be of considerable value in stimulating innovative health-related research which involves our students. It also is expected to foster closer communication with Johnson & Johnson Company scientists.

FACULTY

Dr. Martha Gray was appointed as the Kieckhefer Assistant Professor of Medical Engineering in September. Her appointment is joint between Electrical Engineering and Computer Science (primary) and HST (secondary). Dr. Gray studied computer science as an undergraduate at Michigan State, and earned her PhD degree in Medical Engineering at MIT. During her doctoral and postdoctoral research experiences she has made major original contributions to the understanding of interactions between mechanical loads and the behavior of connective tissue such as cartilage and bone. Professor Gray will establish her research laboratories in the Department of Biomedical Engineering at Massachusetts General Hospital. In this setting she will strengthen our educational and research links with the MGH.

The search for the Cabot Assistant Professor of Artificial Intelligence in Medicine has been completed and an offer has recently been made to a highly qualified candidate. The offer has not yet been accepted.

The academic appointment of Professor Robert Lees (formerly of ABS) was transferred to HST at the request of the Provost and Professor Lees. His research laboratories will remain primarily at the Deaconess Hospital. He will be developing a new clinically relevant course on arteriosclerosis, and will assist us in formulating educational initiatives at the interface of technology and biochemistry/pharmacology/biochemical engineering.

ROGER G. MARK
RICHARD J. KITZ

Mining and Mineral Resources Research Institute

The Mining and Mineral Resources Research Institute (MMRRI) of MIT utilizes its funds to support and encourage new initiatives related to mineral resources at MIT. The MMRRI is affiliated with the Minerals Resources Program of the Bureau of Mines and it continues to participate in the Generic Minerals Technology Centers for Pyrometallurgy and Respirable Dusts of the Bureau. This year, a program of research has been developed on innovative smelting methods for the production of steel as part of the "Steel Initiative" which is a joint activity of the Department of Energy and the American Iron and Steel Institute. Personnel from the MMRRI are also participating in a program of development of a one-megawatt test facility for plasma arc smelting of ferrochromium. The broad goal of the program is to install a state-of-the-art test furnace and operate an experimental program by which it will be possible to enhance the technological base of the domestic ferrochromium industry. Other participants in this program are the South Carolina Research Authority, the Macalloy Corporation, Clemson University, and Arthur D. Little Corporation. The program will be supported by Federal funds.

This year, MMRRI funds have supported the work of four undergraduates in the REMERGENCE Laboratory, and four graduate students from the Departments of Civil, Mechanical, and Materials Science and Engineering. MMRRI funds also have been used to purchase several items of equipment for research programs in the Chemical/Process Metallurgy Group in the Department of Materials Science and Engineering.

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.

During the past year, major scientific achievements by Observatory staff included the discovery of an Einstein ring gravitational lens, the discovery of new methanol maser sources in our galaxy, and the detection by Very Long Baseline Interferometry (VLBI) of a solitary star and of fringes at 3 mm wavelength across the continents resulting in the highest angular resolution ever achieved (50 microarcseconds). Major upgrades of the instrumentation involved successful control of thermal distortions in the Haystack antenna surface that resulted in large improvements in the efficiency of the radio telescope, and completion of the prototype equipment for the nation's Very Long Baseline Array (VLBA).

The Observatory instrumentation at Haystack consists of a 37m diameter paraboloidal antenna enclosed in a radome that is used for radio astronomical observations at 6 mm to 18 cm wavelength. Observatory instrumentation also includes the 18m radio telescope at Westford using 3.5 and 13 cm wavelengths for geodetic VLBI observations, two powerful processors to correlate the VLBI data obtained globally, and two large radar antennas (46m and 67m) that are used in ionospheric and atmospheric studies. During the past year, about 300 researchers from US and foreign institutions have used the Observatory instrumentation, including a large number of graduate and undergraduate students as part of their educational programs. In addition, the Observatory is participating in the NSF Research Experiences for Undergraduates program, allowing 10 students from MIT and other area universities to learn about and contribute to our research programs during the summer months.

The active temperature control system for the Haystack antenna has been in successful operation for almost a year. This has improved the aperture efficiency and stability of the antenna surface by correcting differential thermal distribution between the massive splice plate and light honeycomb panels that form the surface. The temperature of the splice plate is forced to track that of the panels, including a -2.5°C temperature offset to compensate for a surface that was aligned in 1967 for a cold splice plate. Radio holographic maps have been made of the surface that clearly show the thermal distortion produced by improper temperature offsets. These holographic maps, in conjunction with a mechanical model of the antenna produced by our consultants, Simpson, Gumpertz and Heger, Inc. will be used to realign the surface in October 1988 with a goal of .43 mm rms, doubling the efficiency at 50 GHz. This theoretical model also predicts that a major component of the gravitational distortions of the antenna at different elevation angles can be compensated by an augmented thermal control system in conjunction with the use of a deformable subreflector to remove gross astigmatism. We are now proposing to upgrade the antenna for use at 100 GHz, utilizing these factors to correct for gravitational and thermal distortions. Recent measurements show that the antenna surface panels appear capable of supporting this upgrade.

In the past year, the low noise 36–49 GHz (0.7 cm wavelength) maser amplifier receiver was used to detect strong and narrow methanol maser spikes in two transitions at 38.5 and 44.0 GHz. The 20 sources in which detections were made were mainly hot Galactic HII regions. In NGC 6334F the unusual intensity of the lines was 800 Jy at 44 GHz and 200 Jy at 38.5 GHz. Methanol masers were also detected at 36.2 GHz in the Galactic center source Sgr A–E as well as strong, broad emission lines which allowed mapping of the source and showed that the methanol is excited on the shocked edges of a supernova remnant in the Galactic center. Haystack possesses a unique measurement sensitivity at this frequency 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 the final decline of the powerful water vapor maser source in Orion A which is an active region of star formation. The monitoring observations of the flare in this source of $\sim 2 \times 10^7$ Jy allowed a determination of the magnetic field of 0.1 Gauss. The highly luminous ($500 L_{\odot}$) extragalactic water vapor source in the galaxy NGC 3079 was monitored and found to be exceedingly stable which is an unusual characteristic for water vapor sources to have. 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. These transitions, which are closely spaced in frequency and detectable using Haystack's high resolution spectrometer, require widely differing conditions for excitation and allow molecular cloud parameters such as temperature and density as well as dynamical information to be obtained. A correspondence is found in dark cloud regions between the occurrence of the ammonia molecule and the incidence of infrared sources.

*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.

Very Long Baseline Interferometry (VLBI) research benefited from dual operation of both Mark III and Mark IIIA correlators. Seven playback drives can be accessed by both correlators, allowing simultaneous processing of different experiments. Implementation of the high density recording system developed by Haystack engineers continued, with a total of 25 systems operational. All NASA field sites are now equipped, and correlators at Haystack, the Naval Observatory, and the Max Planck Institute in Bonn, Germany regularly process high-density tapes. During the remainder of 1988, most of the additional Mark III systems throughout the world will be equipped with this new technology.

Astrophysical results in VLBI have included the first detections of isolated early-type main-sequence stars in Orion, a minimum size for the prompt radio emission from supernova SN1987A, and numerous measurements to establish distance and proper motion of extragalactic maser sources. Three new gravitationally-lensed sources have been detected through Mark III VLBI; if found to have time-varying compact structure, long-term study might allow measurements of Hubble's constant by determining the time-delay between the two image paths. Haystack staff were among those honored by NASA for the successful space VLBI using the TDRS spacecraft and ground-based antennas, which employed the Mark IIIA correlator and special software developed at Haystack.

The Ridge-based image processing system at Haystack was used during the past year to reduce and analyze data from a wide range of scientific projects. Work continued on a large sample of high redshift quasars, and extensive mapping was done for a new VLA project to investigate the phenomenon of multiple hotspots in the outer lobes of powerful extragalactic radio sources. Many images of gravitationally lensed sources were produced and analyzed, and a VLBI map of the compact double source CTD93 was made. The extensive demand for the resources of the imaging system underlined the need for expansion of the computing capacity at Haystack, and to that end four SUN workstations have recently been acquired, and have been networked together via ethernet, providing the Observatory with a friendly, powerful, flexible, and readily expandable scientific computing environment.

The accuracies achieved for the geodetic measurements of the NASA Crustal Dynamics Project, in which Haystack Observatory plays a significant role, have produced interesting results for several areas, including Alaska, the Western U.S., and the Pacific basin. Using a combination of VLBI data to establish the regional motion, and Global Positioning Satellite measurements to determine the local strain, geophysicists have shown that a narrow block of land on the South coast of Alaska, in an area which is expected to have a large earthquake, is being squeezed uniformly between the Pacific Plate and the Alaskan mainland. Along the San Andreas Fault in California all of the motion between the Pacific and North American Plates which is expected from historical geologic data is accounted for within the land mass of the western U.S. Thus, there is no missing motion off shore which might produce large earthquakes in a difficult-to-measure setting. The speed of the Pacific Plate relative to Japan has been confirmed to be almost nine centimeters per year based on only four years of VLBI data. Finally, the accuracies of baseline lengths from operational measurements are now determined to be less than two centimeters as determined by rms scatter about uniform motion. For test experiments it appears that a repeatability of better than 5 millimeters, with no indication of length change, has been achieved over a baseline of 4000 kilometers between Massachusetts and California.

The Very Long Baseline Array (VLBA), being constructed under NSF sponsorship, consists of a 10-element array of 25-meter telescopes covering the continental USA, Hawaii, and Puerto Rico. 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 high-density recording system has demonstrated that the VLBA system requirements can be achieved by recording and then playing back five Terabits of data on a single reel of tape. The prototype VLBA recorder and digitization electronics built at Haystack have now been installed at the first VLBA telescope at Pie Town, New Mexico. First fringes between Pie Town and the VLA site were obtained in May 1988 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 will be built at Haystack and a "preproduction" of a small quantity of additional units was started in 1988. The VLBA, which is under the direction of the National Radio Astronomy Observatory, will provide VLBI scientists, including those at the Haystack Observatory, with a powerful high resolution astronomical instrument.

The MIT/Haystack Atmospheric Sciences Group which uses the Millstone Hill UHF radar for studies of the upper atmosphere has participated in an extensive World Day program involving similar radar in Peru, Puerto Rico, Greenland, France and Scandinavia. Satellite overflights which serve to link the combined fields-of-view of the multi-station radar observations have permitted near-simultaneous mapping of large portions of the high-latitude ionosphere for studies of global dynamics and storm-time response. Intense radar backscatter from plasma waves in the topside ionosphere has been identified providing a new diagnostic technique for studies of small-scale plasma turbulence and an explanation for a class of radar "false targets". New analysis techniques have been developed which greatly enhance the sensitivity and spectral resolution of incoherent scatter radars. This, combined with a hardware upgrade of radar data acquisition system, has further extended the range of experiments recently undertaken with the Millstone Hill radar systems.

Nuclear Reactor Laboratory

During the past year under a Reactor Sharing grant from the US Department of Energy (DOE), the Nuclear Reactor Laboratory (NRL) continued and strengthened its joint interdisciplinary activities with both MIT and non-MIT collaborators: seven MIT academic departments and interdepartmental laboratories, and 36 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 neutron scattering studies of condensed matter, 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 testing of major components for the multi-year in-core loop studies aimed at radiation dose reduction in light water power reactors and the award of a three-year grant for joint research with Tufts-New England Medical Center in the treatment of brain cancer utilizing the boron neutron capture method. These and other new or expanding programs are expected to more than compensate for the current decrease in neutron beam tube research occasioned by the retirement of Professor Clifford G. Shull.

NEUTRON BEAM TUBE RESEARCH

One of the MITR-II 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. For example, during the past year we have been studying basalts and upper mantle xenoliths from the Hannouba basalt province in eastern China (collaborators: Xiachen Zhi, University of Science and Technology in China, and Song Yan, MIT graduate student).

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, who joined NRL three years ago. Research and/or service-oriented collaborations were established with several MIT research laboratories as well as with other educational and research institutions in addition to those established in previous years, including the University of Massachusetts; the University of Maryland; the University of California, Davis; Harvard; Forsyth Dental Center; and Stanford. Commercial organizations that utilized the NAA expertise of NRL during the past year were Raytheon Company, Sudbury, Massachusetts; GTE, Waltham and Danvers, Massachusetts; Northeast Utilities, Hartford, Connecticut; Genzyme, Boston, Massachusetts; and Combustion Engineering, Windsor, Connecticut.

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. NAA has been used to identify the metal contents of specific enzymes for Professor Christopher T. Walsh and also for Professor Gregory A. Petsko of the Chemistry Department. Cation and anion concentrations were determined in coexisting equilibrium liquid phases of C_8 -lecithin, water, and added salt for Professor George B. Benedek (Physics). Composition of insulators was examined for Ms. Catherine L. Fiore (Plasma Fusion Center). Impurities in different materials were identified for Professor Otto K. Harling and Professor Michael J. Driscoll (Nuclear Engineering Department) for their in-pile coolant loop project.

Dr. Olmez has been actively engaged in a number of environmental research projects. Financial support has been obtained from the Greater Denver Chamber of Commerce for collaboration in the identification of sources in relation to the Metro Denver Brown Cloud Study; from the Pennsylvania Power and Light Company to study groundwater contamination at the Montour Steam Electric Station (SES); and from different utility companies, through the MIT Electric Utility Program, to examine inhalable atmospheric particles in the Boston area.

A powerful new data acquisition system was installed and put into operation last year. Based on a Microvax computer this system allows simultaneous acquisition of 32 spectra from high-resolution, solid-state detectors. This capability permits NRL's trace analysis activities to grow with little constraint due to data reduction considerations.

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. A proposal leading to clinical trials in three years has received funding 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 first year with good progress on all tasks.

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 Office. 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 and by the Sandia National Laboratories (SNL). It has resulted in 10 publications during the past year. In addition, a major report summarizing both the theoretical and experimental work performed in this area from 1983 to 1987 was issued. The 'reactivity constraint approach' has been licensed by the United States Nuclear Regulatory Commission (NRC) for general use on the 5 MW MIT Research Reactor. Closed-loop control experiments can be performed without 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. A major accomplishment of the project during the past year was the demonstration of the control concepts that were first developed and tested on the MIT Research Reactor at the Annular Core Research Reactor that is operated by the Sandia National Laboratories. These tests proved the generic nature of the MIT control methodologies. Research in progress includes 1) the measurement of reactivity using algorithms derived from the dynamic period equation, 2) estimation of the degree of subcriticality of a nuclear reactor, 3) the extension of the nonlinear closed-loop control techniques to the operation of large reactors that are characterized by spatial dynamics, 4) automated reactor startups, and 5) continued work on control laws for the rapid maneuvering of a reactor's neutronic power. One M.S. and one Ph.D. degree were granted during the past year for research performed on this project. There are currently two M.S. and three Ph.D. theses in progress on topics related to this research. Demonstrations of the technology are available by appointment.

DOSE REDUCTION IN NUCLEAR POWER REACTORS

A major interdisciplinary and interdepartmental research program designed to develop radiation dose reduction technology for the nuclear power industry is in progress. It is supported by the Empire State Electric Energy Research Corporation (ESEERCO) and the Electric Power Research Institute (EPRI). Funding at the level of \$2.5 million for four years is available to support the project. Radiation fields in the primary cooling 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 will be characterized, and tests will be carried out to obtain information about optimized water chemistry, surface treatments, and other parameters. Principal investigators are Professor Harling and Professor Michael J. Driscoll, Department of Nuclear Engineering. Others already participating are Dr. Gordon Kohse and Dr. Ilhan Olmez of NRL, members of the MIT Reactor staff, Professors Ronald G. Ballinger, Asashi Kitamoto, 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 departments mentioned above. Three utilities - Public Service Electric & Gas, Duke Power, and Boston Edison - have provided additional financial support. These projects will 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 since the MITR-II and associated expertise represent a unique resource for the nuclear power industry both in the USA and abroad. For example, a new project based on the technology in our loop project is expected to start 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 (LWR's) 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 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 solid state fission fragment track detectors to study the distribution and transport of plutonium in 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; and 7) research activities by Dr. Edward Wrenn of the University of Utah using solid state fission track detectors to analyze the plutonium content of bones.

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) Dr. Robert Tiernan of GTE Sylvania, Inc., continued use of the reactor to study the effect of sodium diffusion through aluminum oxide on the performance of sodium vapor lamps; 2) 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; 3) Dr. James Anderson of the Aircraft Instruments Department of General Electric initiated studies of fast neutron damage to liquid crystal displays, and personnel from the Yankee Atomic Electric Co. irradiated microspheres of Co-59 for use in dose deposition studies. Additional NAA services, including many for research groups outside MIT, were reported in an earlier 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." Grants are made to universities owning reactors to reimburse them for the costs of providing irradiation services and facilities to other institutions (including

teaching hospitals). Under this program, nearly 300 students and 50 faculty and staff from 25 other educational institutions benefited from visits to and use of the MITR during the past year. These figures do not include those reported in a following paragraph for the high school science teachers program. 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 have included: 1) Professors J. Christopher Hepburn and Rudolph Hon used the MITR 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) neutron irradiation of NiP magnet glass alloy discs was used by Professor Abdul Ibrahim, Boston University, for non-destructive analysis by NAA methods; 3) clay layer samples from the Cretaceous/Tertiary Boundary, Gubbio, Italy, that were provided by Professor Charles Officer, Earth Sciences Department, Dartmouth College, were assayed for trace Platinum Group metals by NAA to confirm theories regarding extinction of the dinosaurs by volcanic activity at the end of the Cretaceous Period; 4) samples of ancient ice from the South Pole were analyzed 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; 5) the triple-axis spectrometer on the 6SH4 port was used by Professor Paul E. Sokol, Physics Department, Harvard University, in preliminary studies of the high energy inelastic neutron scattering from hydrogen adsorbed on grafoil; 6) plant seeds for selected Matignon High School students participating in science fair projects were subjected to gamma irradiation under the supervision of Judith A. Howley, Chairperson, Science Department; 7) rock samples were irradiated for Dr. Louis J. Caruso, Geology Department, Stanford University, as part of a study which involves induced fission track techniques to date the sealing of natural fractures in rocks; 8) archeological samples were analyzed by NAA for Professor Alex Kaczmarczyk, Chemistry Department, Tufts University, as an aid in determining the original sources of materials used in the samples; 9) the daily intake of metals by Mariana Island natives, who suffer from a fatal neurodegenerative disease that offsets collagen synthesis and maturation, is being studied in collaboration with Dr. D. B. Hanson, Forsyth Dental Center, Bioengineering Department; 10) research is on-going with Professor G. E. Gordon, University of Maryland, to identify elements other than lead for motor vehicle emissions; 11) analyses were performed for Professor T. Spengler, Harvard School of Public Health, to determine sources of indoor air pollution.

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 02.236, 40 students, 15 visits; 2) Northeastern University, Physics Department, Course PHY 1555, 8 students, 3 visits; 3) University of Massachusetts, Harbor Campus, Department of Physics, Physics 697B, 18 students, 3 visits.

Following successful trials in the previous year, the USDOE separately funded an expanded 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. Three classes (two four-hour days each) were held with very enthusiastic response from the 29 teachers who attended. Two additional classes were held for teachers, administrators, parents, and students (one four-hour day each) with positive response from 27 attendees.

MIT RESEARCH REACTOR

The MIT Reactor completed its 29th year of operation, its 13th 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 at its design power level of 5 MW for 56.7 hours per week. Energy output for the MITR-II, as the upgraded reactor is now called, totaled 232,650 megawatt-hours at June 30, 1988. 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 close to installation in the reactor. The production of dysprosium-165 is being increased for distribution to New York as well as Boston for arthritic knee therapy. Utilization of the neutron beam ports for neutron diffraction experiments decreased substantially, but the triple-axis spectrometer, now refurbished to provide digital computer control of inelastic scattering experiments, may find a user. The number of specimen irradiations was over 1500. Theses and publications on research supported by the reactor are running at about 20 and 60 per year, respectively. A total of 1857 people toured the MIT Research Reactor during 1987.

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.

In 1985-86 a portion of the reactor costs were offset by a first-time grant from DOE in direct support of operation of 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 been conducting 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 DOE and NSF 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, 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 is presently being issued by the NAS-NRC committee.

OTTO K. HARLING

Operations Research Center

The Operations Research Center, established in 1953 as an interdepartmental graduate degree program, completed its 35th year of continuous operation in 1987-88. This year has been one of consolidation and planning for the ORC, as we examined our prospects for future development and understood better the limitations of our present resources. This year the ORC implemented some changes that had been formulated in 1986-87, developed new initiatives, and continued to make plans for a Decision Sciences Center.

Highlights of the year included: admission of the largest, and possibly the best-qualified, incoming class of new students in the history of the ORC; continued discussions concerning the establishment of a Decision Sciences Center at MIT; a major expansion of the computational facilities at the ORC; a very successful symposium on advances in mathematical optimization offered for MIT industry affiliates; and the initiation of an "OR Clinics" program for industry.

The academic and research programs continued in much the same manner as they had in previous years. This year the Operations Research Center had 54 students, 18 that were new to the program. Three new affiliated faculty joined the ORC this year, bringing the total number to 30. Faculty were drawn from the Sloan School of Management, Electrical Engineering and Computer Science, Civil Engineering, Mathematics, Aeronautics and Astronautics, Ocean 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 was promoted to Assistant Director.

Faculty and students at the ORC were engaged in a broad range of activities during the past year. The ORC's research addressed numerous topics in mathematical programming, manufacturing systems, transportation and logistics, public sector applications, applied queueing research, and competitive strategy. This report briefly discusses each of these areas and the ORC's educational activities.

RESEARCH ACTIVITIES

Mathematical Programming and Combinatorial Optimization

Mathematical programming and combinatorial optimization are fields concerned with methods for creating and solving constrained optimization problems. ORC faculty and students continue to make important contributions to these fields.

Ongoing research projects covered both well-established fields of inquiry and emerging topics. Examples in the former category include work on parametric linear programming and anti-cycling pivoting rules and on fixed point theory. The second category includes several ongoing projects. One is concerned with the development of modeling languages for integer programming that would aid a user in developing integer programming models. A second examines projective transformation methods for linear programming, an approach stimulated by the recent pioneering work of N. Karmarkar. Other projects deal with the matroid parity problem, greedoids, which are combinatorial structures that are intimately connected with simple one-pass approaches to combinatorial problems known as "greedy algorithms," and cluster analysis, an area of work that is important in statistical analysis.

In addition, the faculty are studying parallel algorithms and approximation methods for combinatorial optimization problems, and distributed algorithms for nonlinear optimization. They are also exploring promising new methods in integer programming as applied to problems in facility location, production planning, and machine scheduling.

Network Optimization

A number of recent developments have stimulated renewed interest in some of the most classical and fundamental problems in network optimization, such as the shortest path problem, the maximum flow problem, and the minimum cost flow problem. Not only are these problems important in their own right, but also they are used as essential building blocks in solving other network problems. During the last two years, our faculty have made major strides toward developing algorithms for each of these three problems that are proving to be the fastest that have been developed to date.

Other faculty have also continued to work on problems in network synthesis. These investigations have led to new methods for several very large-scale applications.

In emerging areas of network optimization, our faculty and staff made two noteworthy contributions. A doctoral dissertation explored systematically the performance of cyclical permutation heuristics in solving very difficult, large-scale routing problems, including problems with time-window constraints, i.e. with upper and lower limits on when a particular point can be visited. A second project, supported by the National Science Foundation, has obtained many new results on probabilistic variations of classical network optimization problems. These variations, such as the probabilistic minimum spanning tree problem, the probabilistic traveling salesman problem, and the probabilistic vehicle routing problem, suggest exciting new fields of inquiry and, at the same time, are applicable in several contexts.

Manufacturing Systems

International competition, changes in technology, and concerns about low productivity have caused managers to seek fresh approaches for controlling manufacturing systems. As a result, new opportunities have arisen for applying operations research models and methods to support manufacturing decision making. ORC faculty and students were involved in several projects concerned with production scheduling, the design and expansion of flexible manufacturing systems, job shop scheduling, manufacturing learning, work force flexibility, and quality control. Techniques employed included queueing networks, mathematical programming, heuristics, and Monte Carlo simulation. The research was supported by grants from C. S. Draper Laboratory, IBM, and Coopers and Lybrand. This topic represents one of the fastest growing areas of research at the ORC and is attracting increasing numbers of students and faculty.

In view of this interest, the Institute's new Leaders for Manufacturing program, whose Codirector, Professor Thomas L. Magnanti, is also one of the ORC's Codirectors, is a most welcome development.

Transportation and Logistics

Under sponsorship from the GTW Railroad, North American Van Lines, and Burlington Northern Railroad, faculty and staff continued to work on research projects on locomotive scheduling, truck routing, and the logistics of freight movement on a network-wide basis. The principal methodological tools in this research are those of large-scale mathematical optimization. However, the standard techniques available must be modified in important respects if they are to be applied successfully to the types of problems encountered in practice, at both the tactical and strategic levels of planning.

One ORC project, sponsored by the Office of Naval Research, continued to address issues of routing and scheduling of a large fleet of cargo ships during times of national emergency. This problem is enormously complex because of the huge number of relevant variables and operational constraints. A major product of this research was an interactive algorithm to assist schedulers with their numerous tasks. The Military Sealift Command has decided to implement this approach, a step which is now well under way.

Air transportation is another area of interest to ORC faculty. Under Federal Aviation Administration sponsorship, faculty and staff are developing mathematical and simulation models to help air traffic control (ATC) planners to estimate controller workloads at specific points on the en route ATC system. Under the same project, a comprehensive look at the airline safety record of the last eight years not only revealed very significant problems in aviation safety on a worldwide scale, but also suggested causes of concern for the future, such as a potential negative impact of airline deregulation. Yet another area of activity in this general subject is the development of time-dependent queueing models to estimate airport delays under a wide range of conditions.

Another project in the area of air traffic control, sponsored by the C. S. Draper Laboratory, examined methods for effective flow control of air traffic, so that delays due to congestion of en route air sectors is minimized, while unavoidable delays due to airport congestion are sustained, as much as possible, on the ground (before take-off) where they are least costly.

Public Sector Applications

ORC faculty and students developed operations research applications in the public sector in the areas of criminal justice and emergency urban services. Under a grant from the National Institute of Justice, work continued on developing algorithms for computer-aided dispatch systems for police departments. These systems help "911" call-takers and police radio dispatchers to receive and quickly process calls for police service from the public.

Another project attempted, through the use of statistics and age-dependent probabilistic models, to explore the relationship between crime rates and factors such as demographics, deterrence, and prison populations. The project focused in particular on paradoxical aspects of the recent decline in national crime rates, and it attempted to offer explanations for them.

Applied Research in Queueing

Research continued on a three-year grant from the National Science Foundation on analysis of queueing delays and queueing system environments. This research is predicated on the hypothesis that the customer's actual and/or perceived cost of participating in a queueing-line service system are (1) a nonlinear function of the queueing delay and (2) multiattributed. The other attributes, in addition to queueing delay, reflect the customer's attitudes toward the queueing environment and the extent to which the system design or operation leads to "social injustice." The new theoretical and empirical results developed clearly describe customer behavior more accurately than conventional models. This research project has made excellent progress and is now attracting national attention.

A second important development in this area is the derivation of new results on "transactional queueing systems": based only on records of the time instants when a service is initiated or completed at a queueing system, these results allow one to infer important statistics about the underlying queueing process. Major applications abound in the area of deploying and utilizing effectively such increasingly commonplace devices as automatic bank tellers, airport ticketing machines, automatic information booths, and the like.

EDUCATIONAL PROGRAMS AND ACTIVITIES

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 1987-88, 54 students enrolled in these programs--37 PhD candidates and 17 SM candidates. Eight master's degrees and five PhD degrees in operations research were conferred during 1987-88.

Students in the Operations Research Center represent a variety of backgrounds and countries. Nearly 65 percent of ORC students were from foreign countries and 30 percent of the students were women. These students have attained considerable scholastic achievement, as evidenced by the number of fellowships and scholarships they hold: one student held an NSF Fellowship; another student received a fellowship from the Belgian-American Educational Foundation; several other students held scholarships from their respective countries or held Charles Stark Draper Laboratory Fellowships.

In accordance with some of the recommendations of the Committee to Review Operations Research at MIT, which was formed in 1985-86, ORC faculty undertook several initiatives. One recommendation was that the ORC should take steps to help students improve their writing and oral presentation skills. In response, we have instituted a writing requirement, beginning with the 1988-89 academic year, and a writing test will be administered to all incoming students. In addition, faculty will endeavor to increase opportunities for students to write reports and give oral presentations as part of their regular class requirements, as well as within the format of the ORC PhD General Examination.

Another Committee recommendation was to increase emphasis on computer-based operations research in our academic program. Beginning with our next incoming class (Fall 1988), we shall impose computer literacy requirements in the SM and PhD programs.

In 1986-87, the faculty formed a subcommittee to address the question of restructuring the master's degree program. They concluded that the size of the student population (only 17 students last year) prevented effective segmentation into concentration areas; however, the faculty agreed that this might still be a desirable modification in future years should the size of the SM program grow. Another recommendation of the Review Committee concerned the lack of coherent structure in the stochastic systems sequence of subjects available to ORC students. The faculty is developing a course in discrete event optimization to add to the curriculum, and discussions continued about the addition of an advanced modeling course. Further, ORC faculty decided to upgrade the statistics requirement for ORC doctoral students.

As part of an outreach effort to increase students awareness of operations research, ORC faculty have gained approval from the School of Engineering to introduce operations research subjects in the undergraduate curriculum, and two subjects have been developed for the 1988-89 academic year: Probabilistic Modeling in Engineering and Engineering Systems Optimization will be offered as school-wide electives in 1988-89. Two other electives in the areas of decision analysis and data communications may be added in the future.

The ORC instituted a change in requirements for the PhD degree program this year. The requirement of Analysis (18.100) was shifted from the first-year Qualifying Examination to the second-year General Examination.

The Review Committee also recommended an expansion of the scope of decision sciences at MIT, and ORC faculty continued to pursue funding sources to support this initiative. ORC faculty recognized early that this center could not be developed without the addition of significant financial resources. The ORC prepared a proposal for a Science and Technology Center Planning grant, submitted to NSF in February 1988, to fund planning activities related to the proposed Decision Sciences Center. Faculty from the ORC as well as from other divisions within MIT have been organizing a retreat scheduled for October 1988 to examine design alternatives for the proposed center and to discuss funding possibilities. Approximately 40 faculty throughout the Institute have expressed interest in the initiative.

Early in 1988, the ORC received funding from AT&T Bell Laboratories to develop a computational laboratory. We have assembled a network of Macintosh computers for student and faculty use, including three color Mac II workstations, five Mac Pluses with external hard disk drives, a cartridge tape, and a Laserwriter Plus. In addition, the ORC received four Digital VAXstation 2000s and a laser printer to support our Athena curriculum development projects. The ORC was awarded two IBM Personal Systems/2 in a contest underwritten by IBM, for software development for the IBM PC that was successfully ported to the PS/2. The addition of this equipment to the ORC has been a tremendous benefit to the productivity of students and staff alike. Some of this equipment was long-awaited, which has made its appearance that much more satisfying.

The Operations Research Center regularly offers professional courses during the Summer Session. In the summer of 1987, the faculty offered three such programs: "Decision Analysis: Basic Concepts and Applications," Decision Analysis with Multiple Objectives: Concepts and Applications," and "Operations Management in the Service Industries."

In addition to the Summer Session program, ORC faculty participated in OR Clinics. The Clinics were arranged as half-day workshops focused on particular problems presented by a company representative. We are enthusiastic that this format can improve the Center's outreach to business and industry and also ensure the introduction of real-world problems into the research environment. Both ORC faculty and graduate students are expected to participate in future Clinics.

ORC faculty, in cooperation with the Center for Transportation Studies, presented a one-and-one-half day symposium, "Recent Developments in Mathematical Programming," in April 1988. Over sixty representatives from business and industry, mostly in the areas of transportation, manufacturing, and logistics, attended. Seven ORC faculty and three alumni made presentations on theoretical and applied topics that reflect the cutting edge of mathematical programming research. The symposium was very successful and will be repeated in future years.

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 Robert Tarjan, from the Mathematics Department, Princeton University, and AT&T Bell Laboratories; P. O. Lindberg, from KTH (Royal Institute of Technology), Stockholm; George Nemhauser, from the School of Industrial and Systems Engineering, Georgia Tech; and Laszlo Lovasz, from the Computer Science Department, Eotvos University, Budapest. Special seminars were given by Michael Todd, School of Operations Research and Industrial Engineering, Cornell University; Alexander Schrijver, Department of Econometrics, Tilburg University, The Netherlands, and Centrum voor Wiskunde en Informatica, Amsterdam; and Ron Shamir, School of Mathematics, Tel Aviv University.

In summary, the year 1987-88 has been productive and gratifying. The students in the program continued to be of the highest calibre, thus strengthening our educational program and providing a stimulating environment for our faculty. Our research program has grown slightly in volume during the past year, and we are hopeful that this trend will continue. Our faculty have generated some new funding sources, and this is a positive development. We are very encouraged by the interest of faculty from throughout the Institute in the Decision Sciences Center, and we shall endeavor to find appropriate avenues for funding this initiative.

THOMAS L. MAGNANTI
AMEDEO R. ODONI
Codirectors

Plasma Fusion Center

During the past year, technical progress has been made in all Plasma Fusion Center (PFC) research programs. The Plasma Fusion Center is recognized as one of the leading university research laboratories in the physics and engineering aspects of magnetic confinement fusion. Its research programs have produced significant results on several fronts: (a) the basic physics of high-temperature plasmas (plasma theory, RF heating, free electron lasers, development of advanced diagnostics, and intermediate-scale experiments on the Versator tokamak and Constance mirror devices), (b) major confinement results on the Alcator C tokamak, including pioneering investigations of the stability, heating, and confinement properties of plasmas at high densities, temperatures and magnetic fields, (c) experiments on the medium-scale TARA tandem mirror, including the development of novel MHD stabilization techniques in axisymmetric geometry, and (d) a broad program of fusion technology and engineering development that addresses problems in several critical subsystem areas (e.g., magnet systems, superconducting materials development, 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 \$26 million. There are approximately 294 personnel associated with PFC research activities. These include: 29 faculty and senior academic staff, 71 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; 88 research scientists and engineers and 22 visiting scientists; 31 technical support personnel; and 38 administrative and support staff.

ALCATOR CONFINEMENT EXPERIMENTS

After many years of outstanding leadership of the Alcator experimental program, in August, 1987, Ronald Parker became Project Physicist for the Compact Ignition Tokamak (CIT) at Princeton Plasma Physics Laboratory (PPPL). Subsequently, Ian Hutchinson was appointed Head of the Confinement Experiments Division, and Ronald Parker was named Director of the Plasma Fusion Center effective July 1, 1988.

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 is headed by Stephen Wolfe as physics coordinator. 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).

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-cyclotron-heated plasmas, with the goal of understanding the physics of RF heating, confinement, stability, impurity control, 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 Spring 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.

Significant progress has been made in the construction of the Alcator C-MOD facility. Over sixty percent of the hardware costs have now been committed for component fabrication by various industries. Major items include: \$1 M for the toroidal field magnets (Mitsubishi, Japan), \$0.3 M for the vacuum vessel (Meyer Tool, Illinois), \$1.8 M for the support structure (Thyssen, Federal Republic of Germany; Ladish, Wisconsin; Southern Bolt, Louisiana), \$1.6 M for the main power supplies (Robicon Corporation, Pennsylvania), \$0.2 M for RF power-supply modification (Uptegraff, Pennsylvania; Varian, Massachusetts), \$2.6 M for site modification and cell construction in the east wing of the Nabisco Laboratory (Vappi & Co., Cambridge), and \$1.1 M 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 site for experimental plasma physics research.

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 is under construction, several of the scientific staff are 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. Examples include extensive (1-2 year) assignments at the Joint European Torus (JET) in the U.K. (Robert Granetz, Steven Knowlton), and shorter assignments (up to 6 months) at other major centers such as the Princeton Plasma Physics Laboratory (Catherine Fiore, John Rice), the Max Planck Institute for Plasma Physics (Evelio Sevillano, Kevin Brau), and the Japan Atomic Energy Research Institute (Yuichi Takase). These collaborations help to establish good international relations as well as enhance the experience and productivity of the scientific staff.

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 University. 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 should be installed on TFTR in July, 1988, and PFC staff will be stationed at Princeton to carry out the experiments.

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), should begin operation later this year. It is anticipated that Alcator scientific staff will participate in the recommissioning process as well as in the initial experiments on the reconfigured machine.

Scientists from the Confinement Experiments Division have participated in various capacities in the national CIT program. In addition to Ronald Parker's oversight of CIT physics, 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 quadripartite collaboration between the U.S., Europe, Japan, and the U.S.S.R.

Completion of TARA Experiments: The experimental program on the TARA tandem mirror (Richard Post, Jay Kesner) was completed in 1987, and many of the resources and personnel transferred to Alcator C-MOD and other PFC activities.

The final experiments on TARA included a detailed study of trapped-particle modes, which were found to ultimately limit plasma performance, the development of new MHD stabilization techniques in axisymmetric geometry, and further studies of heating and transport. This work was presented to the Magnetic Fusion Advisory Committee (MFAC) as part of the completion of the TARA program, and received favorable technical reviews. The experimental results will be presented at the next International Atomic Energy Agency (IAEA) meeting on Plasma Physics and Controlled Thermonuclear Fusion to be held in Nice in October, 1988.

Despite the difficulties in completing a major experimental project, the TARA closeout proceeded relatively smoothly, considering the large staff that was involved in the program. There was some attrition, but many of the technical personnel were transferred to other PFC programs, including Alcator C-MOD, CIT design and engineering, and development and technology activities. Also during the past year, several of the TARA staff participated in the planning of new efforts, including the design of the proposed Versator-Upgrade and the gyrotron millimeter-wave heating system for CIT. New initiatives are also underway with NASA, e.g., in the development of spin-cast plasma diagnostics for the Space Station.

The TARA equipment and facilities are in the process of being reassigned. Some of the larger hardware items that are not reusable within the PFC or MIT have been transferred to other government research and development facilities. One end of the TARA cell houses some of the experiments in the Coherent Electromagnetic Wave Generation Division which produce large X-ray fluxes. The other end of the cell houses a Constance-scale experiment using the TARA anchor, supported by Spire Corporation under contract to DOE. Plans call for the installation of Versator-Upgrade in the central portion of the TARA cell. The laboratory support space in the west wing of the Nabisco Laboratory is being used for Alcator C-MOD, CIT engineering, and various diagnostic, microwave, and NASA-supported projects.

APPLIED PLASMA PHYSICS RESEARCH

The primary objective of the Plasma Fusion Center Applied Plasma Physics Research Division, headed by Ronald Davidson, is to develop the basic experimental and theoretical understanding of plasma heating and confinement properties. Present applied plasma physics research activities include: experimental research on the Versator II tokamak (Miklos Porkolab and Stan Luckhardt); experimental research on the Constance B mirror device (Richard Post and Donna Smatlak); fusion theory and computations (Abraham Bers, Bruno Coppi, Ronald Davidson, Thomas Dupree, Jeffrey Freidberg, Jay Kesner, Kim Molvig, and Dieter Sigmar); advanced diagnostic development (Richard Petrasso and Paul Woskov); and ionospheric and space plasma theory (M.C. Lee and Kim Molvig).

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) initial tests showed the feasibility of lower-hybrid fast-wave current drive at 2.45 GHz using a novel slotted waveguide launcher; (c) a new electron cyclotron transmission (ECT) diagnostic was installed and tested for purposes of measuring the non-thermal component of the electron energy distribution in the presence of high-power RF fields; (d) a new dielectric-loaded waveguide array operating at 800 MHz was fabricated (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 (e) using lower-hybrid current drive, plasmas with high values of poloidal beta ($\beta_p \approx 4$ and $\epsilon\beta_b \lesssim 1.3$) were established. This concept may eventually lead to tokamak operation in the so-called "second-stability" regime, a potentially important result for future reactor applications. While in the present experiments the pressure originated from the energetic tail electrons, the plasma remained "grossly" stable. Finer-scale stability properties will be examined in the near future. Bulk plasma heating via ion Bernstein waves will also be attempted. Theoretical analysis indicates that this experiment may also be operating near the second-stability regime.

In FY88, a new tokamak facility, called Versator-Upgrade, was proposed to replace the Versator-II and Constance programs for the 1990's (Miklos Porkolab, Richard Post). 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 DOE review of the Versator-Upgrade proposal was very favorable. 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. The device would be located in the central section of the TARA cell, and experimental operation would begin in late FY90, at which time the operation of Versator-II and Constance would terminate. The purpose of the Versator-Upgrade program is to develop a flexible tokamak facility with major emphasis on current profile control in a shaped plasma with relatively high safety factor, $q(r)$, and high $\epsilon\beta_p$, where $\epsilon = R/a$ is the inverse aspect ratio. Particular emphasis will be placed on the following: (a) current profile control and its experimental measurement and monitoring using Faraday rotation techniques; (b) study of plasma stability properties near the Troyon (first-stability) limit, including the influence on stability of active profile control; (c) the development and testing of novel diagnostic techniques relevant to CIT, Alcator C-MOD, and ITER; and (d) the eventual increase of plasma beta with additional heating power to enter the second-stability regime. This would be facilitated by strong current profile control with $q(0) \gtrsim 2$ as well as the addition of a conducting shell. The Versator-Upgrade program would add considerable strength and breadth to the plasma physics and graduate training program at the Plasma Fusion Center during the next decade.

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. This research is carried out with participation by four graduate students.

During the past year, the studies of hot electron velocity-space diffusion by ECRH and whistler micro-instability electric fields were completed. End-loss-produced by RF diffusion into the mirror loss cone was found to be the dominant loss mechanism for the hot electrons. The unusual baseball-seam hot electron equilibrium has now been quantified. The experimentally-determined pressure profiles have been used in theoretical calculations, but the results do not lead to an explanation of the manifest stability of the hollow pressure profiles. Theory predicts that the plasma should be unstable within a few microseconds, while experimentally, the plasma is observed to be macroscopically stable for fractions of a second.

The confinement of impurity ions in Constance is being investigated in order to advance the physics understanding of electron cyclotron resonance (ECR) ion sources. ECR ion sources are widely used in accelerators for basic nuclear physics research but are not well understood. High-Z ion confinement is the key physics issue which needs to be addressed. Detailed measurements of the ion charge-state distribution in Constance have been made and are now being compared with the predictions of several confinement models. Experiments in which ion cyclotron resonance heating (ICRH) is used to selectively enhance the production of particular charge states have provided promising results.

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) kink and ballooning-mode stability of advanced-shaped tokamak plasmas; (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 free electron lasers including the development of advanced concepts, studies of harmonic generation, and nonlinear models for saturation and efficiency enhancement; and (m) theoretical studies of the nonlinear evolution of the electron whistler instability in magnetospheric plasmas.

FUSION TECHNOLOGY AND ENGINEERING

The 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 1987-88 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 (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.

The Compact Ignition Tokamak (CIT) is proposed as a national project, to be completed in 1996, 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 Project Engineer, and Ronald Parker served as Project Physicist during 1987-88. Richard Thome is manager for the poloidal field system, and Daniel 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 F. McClintock and R. Pelloux.

The International Thermonuclear Experimental Reactor (ITER) is a design and R&D activity which has grown out of a U.S./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 and electromagnetics. It is hoped that this activity will result in the decision to proceed with the construction of an international fusion test reactor in the early-to-mid 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 for inclusion on the TEXT tokamak at the University of Texas. The method would induce an influx of circulating particles in order to reduce impurity generation and to enhance beam heating. The divertor development group is also developing innovative approaches to integrating tokamak magnets. These approaches would build the toroidal and poloidal field coils as single units to increase system maintainability.

The principal task involving the use of internally-cooled, cabled superconductors (ICCS) is the design of the two-meter outer-diameter Multipurpose Coil (MPC) which is a prototype of the central solenoid (ohmic heating) coils for fusion reactors. This task is multifaceted. It involves several collaborative efforts including: conductor sheath development in conjunction with Professor R. 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 reactor 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 of the type to be used for the outer coil of the MPC before the coil design is finalized. Conductor tests are being performed in conjunction with the Lawrence Livermore National Laboratory (LLNL), which is responsible for the design and construction of the inner coil of the MPC.

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. Current densities of 10⁴A/cm² at 20 T achieved in 1986, are expected to rise by an order-of-magnitude if the appropriate phase can be formed. Considerable activity has been underway during 1987-88 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 internally-cooled, cabled superconductor (ICCS) design. To ensure that the conductors under development will meet the requirements of early commercial MHD magnets, an analytical and design effort has been performed on a preconceptual magnet based on input from the MHD community. Conceptual designs of space-based magnet systems for both linear and disk multi-megawatt MHD generators have also been developed.

FUSION SYSTEMS

The Fusion Systems Division, headed by Daniel Cohn, investigates several aspects of fusion reactor conceptual design and develops advanced diagnostics. Research areas include: Compact Ignition Tokamak (CIT) design activities (Leslie Bromberg, Daniel Cohn); ITER design activities (Richard Myer and Jeffrey Freidberg); commercial reactor design studies (Leslie Bromberg, Daniel Cohn, and John Williams); safety and environmental studies (Mujid Kazimi); X-ray and gamma-ray diagnostic development (Richard Petraso); 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 have been evaluated. System studies are being carried out on alternative

heating technologies - particularly neutral beams and electron cyclotron resonance heating. Burn dynamics and control are being studied, and options for minimizing the start-up auxiliary heating power have been evaluated. Studies of steady-state CIT operation are also being performed, assuming that some auxiliary heating is present. There is also participation in the planning of advanced diagnostics for CIT. Finally, work is being pursued on various ohmic heating (OH) transformer designs, including very-high-performance upgrade options.

International Thermonuclear Experimental Reactor (ITER) Design: ITER design activities include analysis of RF current drive as a means to reduce start-up requirements and studies of burn control. The burn control studies include both passive and active techniques. Variable auxiliary heating has been identified as a particularly attractive approach. A high-field, high-aspect-ratio ITER design variation is also being evaluated. Potential advantages include reduced current-drive requirements, decreased tritium consumption, reduced fusion power, and smaller machine size.

Commercial Reactor Studies: The Plasma Fusion Center is participating in the national ARIES commercial reactor design. Activities include participation in one of the design options - a super-high-field device that uses advanced low-temperature superconductors and advanced structural materials. Among the potential advantages of this design is the possibility of operation with advanced fuels. Designs using high-temperature superconductors are also being evaluated.

Safety and Environmental Studies: Professor Mujid Kazimi served as a member of the National Senior Committee on Environmental, Safety and Economic Aspects of Fusion Energy. The group developed models to evaluate fusion concepts using a wide range of possible materials choices and power densities. The study identified significant potential advantages of fusion in inherent safety and waste disposal. 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 three X-ray system developed at the Plasma Fusion Center is being used on the TEXT tokamak at the University of Texas to obtain high-spatial, high-temporal, and moderate-spectral resolution. The system employs surface-barrier detectors and provides images of X-ray radiation in the 1 to 5 keV range. The surface-barrier detectors can also be used as particle detectors. The experimental results have significantly improved the understanding of impurity transport.

A gamma-ray diagnostic is being designed for CIT. Gamma rays at 16.7 MeV are produced by the $D + T \rightarrow He^3 + \gamma$ reaction. A Monte-Carlo coupled neutron-photon transport code is used to model the expected γ -ray spectrum incident on a Compton spectrometer backed by a Cerenkov detector. 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 $D - He^3$ reaction rates in RF-heated plasmas by measuring the gammas produced in the $D + He^3 \rightarrow Li^3 + \gamma$ reaction.

Millimeter-Wave and Far-Infrared Laser Diagnostics: A concept has been developed for the measurement of alpha particle velocity and spatial distributions in a burning plasma by the scattering of millimeter-wave gyrotron radiation. This measurement will provide information on a fundamental aspect of self-heated plasmas. A scattering system will be employed by PFC personnel on the TFTR tokamak at Princeton University, followed by implementation on the CIT device. Based on this concept, work has also been initiated on the JET tokamak.

A device for very sensitive measurement of RF surface resistivity at frequencies in the 100 to 3000 GHz range has been developed using a special cavity approach. This device will provide new information about high-frequency conductor behavior, including properties of high-temperature superconductors.

COHERENT ELECTROMAGNETIC WAVE GENERATION

The primary objective of the Coherent Electromagnetic Wave Generation Division, headed by George Bekefi and Richard Temkin, is to develop a basic experimental and theoretical understanding of coherent radiation generation by free electrons for wavelengths in the 1 μ m to 1 cm range. Particular emphasis is placed on the development of free electron lasers, gyrotrons and novel radiation sources. A second area of research (Ronald Davidson, Jonathan Wurtele) relates to theoretical studies of the basic equilibrium and stability properties of nonneutral plasmas and intense charged particle beams, with applications to high-current accelerators, coherent radiation generation, and nonneutral electron flow in high-voltage diodes. A third 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. A fourth area of research is the relativistic magnetron, including studies of phase locking of magnetron operation at high peak power.

In the area of gyrotron research, pulsed gyrotrons with output powers in the 400-650 kW range at frequencies between 140 and 250 GHz 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). Harmonic gyrotron emission at submillimeter wavelengths is also under investigation.

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. Under proper circumstances this phase shift can have a sign such that the electromagnetic wave is refracted towards the axis of the electron beam, in a manner somewhat akin to the guiding properties of an optical fiber. This theoretically predicted behavior has important implications. Optical guiding would mitigate the effects of diffraction, and thereby allow the length of FEL wigglers to exceed the Rayleigh range. Such long wigglers are needed if free electron lasers are to operate either in the vacuum ultraviolet (VUV) or at high efficiencies in the infrared wavelength regime. Using the MIT free electron laser facility, the phenomenon of optical guiding has been demonstrated successfully. This is the first such experimental demonstration.

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. A novel free electron laser device using a gyrotron-powered electromagnetic wave wiggler has been designed. A long-pulse relativistic magnetron microwave source using a superconducting magnet has also been designed and is under construction. The power supply for this experiment, (700 kV, 800 A, 1 μ s) has been built and is now being tested in the TARA cell area. A far-infrared molecular gas laser with narrow bandwidth emission has been demonstrated. Finally, a 140 GHz cyclotron autoresonance maser (CARM) amplifier with high efficiency has been designed, and numerical modeling has been carried out.

Very-short-period microwigglers for free-electron-laser applications are of considerable current interest. Besides their compactness, such systems have the advantage of producing high-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 in the manufacture of multi-channel magnetic recording heads for space-borne applications.

In addition to the above work, 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.

APPOINTMENTS AND PROMOTIONS

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

Appointments include: Alan Beatrice (American Science & Engineering), appointed Assistant Fiscal Officer in the Fiscal Office; Xing Chen (Massachusetts Institute of Technology), appointed Postdoctoral Associate in the Fusion Systems and Technology Division; Joseph Davin (Massachusetts Institute of Technology), appointed Mechanical Design Engineer in the Confinement Experiments Division; Stephen Fairfax (Kaiser Systems), appointed Electrical Engineer in the Confinement Experiments Division; Jun Feng (Massachusetts Institute of Technology), appointed Postdoctoral Associate in the Fusion Technology and Engineering Division; S. Pekka Hakkarainen (Massachusetts Institute of Technology), appointed Postdoctoral Associate in the Confinement Experiments Division; Chi-Tien Hsu (Massachusetts Institute of Technology), appointed Theoretical Research Scientist in the Coherent Electromagnetic Wave Generation Division; Min-Chang Lee (Research Laboratory of Electronics), appointed Theoretical Research Scientist in the Applied Plasma Physics Division; L. Thomas McCallum (Massachusetts Institute of Technology), appointed Assistant Fiscal Officer in the Fiscal Office; Makoto Takayasu (Massachusetts Institute of Technology), appointed Experimental Research Scientist in the Fusion Technology and Engineering Division; Kenyatta Vonmuller (Loft 21 Association), appointed Assistant Fiscal Officer in the Fiscal Office; and Peter Winn (Koch Processing Systems), appointed Design Engineer in the Fusion Technology and Engineering Division.

During the past year, promotions in the Plasma Fusion Center have included: John Cochrane, promoted to Assistant Director for Administration, Plasma Fusion Center; Ian Hutchinson, promoted to Head, Toroidal Confinement Division; Donna Smatlak, promoted to Leader, Constance Experimental Research Group in the

Applied Plasma Physics Division; Michael Steeves, promoted to Associate Leader, Superconducting Magnet Development Group in the Fusion Technology and Engineering Division; and Paul Woskov, promoted to Leader, Millimeter-Wave and Infrared Laser Diagnostics Project in the Fusion Systems Division.

During the past year, the Plasma Fusion Center has also hosted several 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; Dr. Won-Ho Choe (University of Illinois), MHD stability of tokamaks; Prof. John Davies (Clark University), theory of free electron lasers; Mr. Grant Deane (Trinity College, England), density concentration in pellet-fueled Alcator discharges; Prof. Steve Fetter (Harvard University), economic, environmental and safety aspects of fusion; 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. Shuichiro Fuchino (Electronic Technical Laboratory, Japan), superconducting magnet technology; Dr. Johan Goedbloed (FOM-Institut voor Plasmafysika "Rijnhuizen," the Netherlands), MHD equilibria in torsatrons and stellarators; Dr. Michael Hayes (Dartmouth College), electron cyclotron heating on Versator II; Dr. Atsusho Ishiyama (Waseda University, Japan), superconducting magnet technology; Dr. Elisabeth Källne (Joint European Torus), soft X-ray emission from tokamak plasmas; Dr. Jan Källne (Joint European Torus), soft X-ray emission from tokamak plasmas; Mr. Ulrich Lampen (Fachhochschule Technical University, Federal Republic of Germany), design and evaluation of superconductors; Dr. Chee-Seng Lim (National University of Singapore), theoretical ionospheric plasma physics; Dr. Guishi Luan (Institute of Plasma Physics, P.R.C.), advanced tokamak magnet systems and plasma-wall interactions; Dr. Igor Maksimov (Gorky State University, U.S.S.R.), superconducting magnet technology and cryomechanics; Mr. Philippe 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. Frederick Seguin (American Science and Engineering), X-ray tomography on TARA and Constance; Dr. Abhijit Sen (Physical Research Laboratory, India), intense beam physics; Dr. Trach Minh Tran (Ecole Polytechnique Federale de Lausanne, Switzerland), gyrotron and free electron laser theory; Dr. Han S. Uhm (Naval Surface Weapons Center), theoretical studies of beam-plasma systems with intense self fields; Dr. Chun-Yi Wang (Zhejiang University, P.R.C.), high-frequency gyrotrons and novel concepts for free electron lasers; Dr. Reich Watterson (Science Research Laboratories), novel laser scattering diagnostics; Dr. John Wesson (Joint European Torus), teaching Course 22.161, MHD Theory of Magnetic Fusion Systems-II; Dr. Robert Witt (University of Wisconsin), stress analysis of structural support systems for the CIT poloidal field coils; Dr. Leslie Woods (Mathematical Institute, Oxford University), plasma confinement theory; Dr. Xin-Zi Yao (Institute of Physics, P.R.C), diagnostic development; and Mr. Roberto Zanino (University of Turin), impurity transport in tokamak divertors.

GRADUATE DEGREES

During the past year, the following students graduated with theses in plasma fusion and related areas: Xing Chen, Ph.D. in Physics; Charles Gibson, S.M. in Mechanical Engineering; S. Pekka Hakkarainen, Ph.D. in Nuclear Engineering; Scott Haney, Ph.D. in Nuclear Engineering; Samuel Hokin, Ph.D. in Physics; Douglas Kirkpatrick, Ph.D. in Physics; Yun-Tung Lau, Ph.D. in Physics; John Massida, Ph.D. in Nuclear Engineering; John Moody, Ph.D. in Physics; Behzad Mottahed, Mech.E. in Mechanical Engineering; Jacek Myczkowski, Ph.D. in Nuclear Engineering; Thong Phamduy, S.M. in Mechanical Engineering; John Voccio, S.M. in Mechanical Engineering; Robert Witt, Ph.D. in Nuclear Engineering; and David Warburton, S.M. in Mechanical Engineering.

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

Reflections: On July 1, 1988 I will be succeeded by Ronald Parker as Director of the Plasma Fusion Center. Looking back over the past ten years, it's been an exceptional period of technical accomplishments, growth, and consolidation for the Plasma Fusion Center, which is now the largest on-campus MIT laboratory. This is really the result of the efforts of many people, whom I thank, including faculty, staff, students, members of the MIT administration, and federal funding agencies.

A few words for my successor are appropriate. Ronald Parker's career and accomplishments as a plasma physicist and leader of the Alcator experimental program have been truly outstanding. We are indeed fortunate that he has accepted the challenge of leading the Center through its next era of accomplishments. May the Center continue its record of pioneering achievements, and may Ron be as fortunate as I have been in being the beneficiary of the dedicated efforts of so many competent people.

RONALD C. DAVIDSON

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 continuation 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, RLE has branched out into a number of directions, and in fact, is the root from which many other MIT laboratories have grown. 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). This support is combined with substantial contributions from industry and private foundations. Although RLE has a very heterogeneous character, its organization can be seen in two major thrusts: one focused on electronics and optics, and the other centered on language, speech, and hearing. In addition, there are seven smaller focus areas and some individual activities which have a small amount of coupling to other projects within RLE.

ELECTRONICS AND OPTICS

Research in this thrust area ranges from the production and characterization of electronic materials to processing techniques, device physics, high-performance integrated circuit design, and specialized system architectures. RLE brings together experts in physical chemistry, condensed matter physics, electronic materials, device design and characterization, processing innovation, high-performance integrated circuit design techniques, and architectural strategies for special purpose applications which include digital signal processing and image processing.

An increased effort has been made in the molecular beam epitaxy area with the hiring of Professors Jesus del Alamo and Leslie Kolodziejski to the EECS faculty. Together with Professor Clifton Fonstad, they comprise an important new endeavor in materials growth for electronic and optical applications. Capability in III-V and II-VI materials growth will complement RLE's studies in quantum effect electronic devices and special purpose solid-state optical lasers. These two new faculty members have also brought about a significant change in the RLE Joint Services Electronics Program, which now has a component in electronic and optical materials. Professor Sylvia T. Ceyer continued experiments on the dynamics of molecule interactions with solid surfaces to understand the origin (on a microscopic level) of observed differences in surface-chemical reactivity at high and low gas pressures. She has discovered a new mechanism for dissociative chemisorption: collision-induced dissociation of adsorbates. This process is particularly important in high-pressure environments such as industrial heterogeneous catalysis, plasmas, and chemical vapor deposition. Professor Keith Nelson has studied how femtosecond light pulses affect matter, and has demonstrated that these pulses unavoidably undergo impulsive stimulated light scattering in most materials. This alters both the material and pulse in easily measurable ways, and suggests the possibility of optical control over microscopic structure and material behavior.

Under the direction of Professor Henry I. Smith, advances were made in the Submicron Structures Laboratory on the establishment of technologies to fabricate submicron structures and to understand deep-submicron quantum transport. Surprisingly, Professor Smith discovered that the deleterious hot-electron effects usually noted in silicon MOSFETs with channel lengths below $0.15 \mu\text{m}$ actually decrease, apparently because source-drain transit times are shorter than electron energy-relaxation times. Electron back diffraction in gallium arsenide lateral surface superlattices was also demonstrated. This revealed a quantum mechanical effect that could be the basis for highly miniaturized electronic devices of the future. Principal Research Scientist John Melngailis has utilized focused ion beam techniques for implantation and lithography as well as ion beam-induced microfabrication and machining. Using gradient doping techniques between the contacts of a Gunn diode, a microwave frequency source has been produced that can be tuned from 6 to 23 gigahertz. In addition, the first gold film was produced with a $0.2 \mu\text{m}$ linewidth by ion-induced deposition with a very low resistivity. This will be exceedingly useful in the repair of x-ray lithography masks. Professor Carl V. Thompson continues to focus on the understanding and control of microstructural evolution during thin film processing. A general

model that allows quantitative predictions of the grain growth rate and final grain sizes in polycrystalline silicon films was produced. The model was based on annealing time, annealing temperature, film thickness, dopant type and concentration, and ion bombardment flux dose and species.

In the optics research area, Professor Clifton Fonstad is examining the production of high-performance optoelectronic devices based on the use of sophisticated III-V heterostructures to achieve intense nonlinear optical and electro-optical effects. State-of-the-art multiple quantum well heterostructures have been successfully grown in two material systems, gallium aluminum arsenide/gallium arsenide and indium gallium aluminum arsenide/indium phosphide, for incorporation in waveguide devices. Professor Hermann A. Haus successfully fabricated waveguides by ion bombardment in wafers containing gallium arsenide/gallium aluminum arsenide quantum layers. Since these layers exhibit enhanced optical nonlinearities, it is important that device applications develop waveguide fabrication techniques in these structures. Professor Erich Ippen produced the first measurements of femtosecond electronic energy transport in metals, discovered new femtosecond dynamics in semiconductor laser amplifiers, and created a new laser source of ultrashort infrared pulses. Professor James G. Fujimoto has concentrated on the development of new femtosecond laser generation techniques to investigate ultrafast phenomena. He also developed new techniques for extremely high gain in wide bandwidth lasers, and continues to study ultrafast carrier dynamics in gallium arsenide and aluminum gallium arsenide in collaboration with Professor Ippen. New experiments using picosecond and femtosecond pulses for laser surgery have shown that short pulses with extremely high peak intensities and low pulse energies can be used for applications which require nonlinear laser-tissue interaction. Hence, there is the possibility of using these pulses to perform surgical incision with micron localizability on transparent structures within the eye. Professor Peter Wolff has examined the nonlinear optical properties of narrow gap semiconductors such as mercury telluride (HgTe), mercury cadmium telluride (HgCdTe), and mercury manganese telluride (HgMnTe). The goal of this work is to understand mechanisms of optical nonlinearity in semiconductors, and to develop materials with large, fast optical nonlinearities. Recently, a record picosecond-speed nonlinearity was realized in mercury cadmium telluride ($\text{Hg}_{0.94}\text{Cd}_{0.16}\text{Te}$), which has a saturation power much larger than other optical nonlinearities in semiconductors. Professor Peter Hagelstein is developing a small-scale extreme ultraviolet laser facility with a soft x-ray detector. Computer codes are also being developed for the simulation of numerous topics in atomic physics and quantum mechanics, both as an aid to x-ray laser design and to provide detailed theoretical understanding of atomic-level phenomena.

In condensed matter physics, theoretical and experimental studies are coordinated to provide insight into a variety of novel states of matter. Professor A. Nihat Berker continued to exploit the renormalization-group method in a highly efficient and accurate way in order to produce phase diagrams which reveal and resolve ambiguities in currently available experimental results. These new methods will be applied to surface systems and quantum mechanical models for high T_c superconductors. Professor John Joannopoulos has utilized theoretical techniques to study reconstructions on the polar surfaces of gallium arsenide, the hydrogenation of silicon and germanium (111) surfaces, and structural transitions on the (100) surface of germanium. These techniques are focused on real materials, using *ab initio* quantum mechanical theoretical techniques to predict microscopic properties of many phenomena such as the detailed nature of silicon-hydrogen and germanium-hydrogen bonds and their relation to the formation of surface dipole moments and relaxations on (111) surfaces. Professor Patrick Lee has investigated quantum transport theory in small structures. It has been shown that current is controlled by the weakest link in narrow MOSFETs, and as gate voltage varies, switching occurs between different weak links. These phenomena have now been extended in order to understand nonlinear source-drain current voltage saturation phenomena in very small devices, and also to provide insight into a single quantum state in these systems. In collaboration with Professors Dimitri A. Antoniadis and H. I. Smith, Professor Marc Kastner has used new fabrication techniques to observe conduction phenomena in MOSFETs where the inversion layer is only 25 nanometers wide. These devices will provide the basis to explore a magnetic field-induced transition to a different state, with conductance about ten times higher than that in a zero field at very high magnetic fields (4 tesla). These experimental studies, combined with Professor Lee's theoretical investigations and Professor Smith's structure and device studies, are part of a major RLE focus on transport in very small devices. Now that the National Synchrotron Light Source at Brookhaven National Laboratory is operational, Professor Robert J. Birgeneau has used this source for high-resolution x-ray scattering experiments aimed at understanding the fundamentals of surface structures. These techniques have been used to provide direct evidence of Ag (110) surface thermal roughening. The high resolution provided by x-ray scattering measurements allows relatively simple data analysis for a wide variety of surface structures as they vary through multiple phase transitions. Professor Simon Mochrie is also studying surface roughness, but from the viewpoint of the relationship of growth kinetics to the surface morphology of several materials. Here, the goal is to understand the proper surface conditions for satisfactory epitaxial growth.

In the VLSI circuit design area, Professor John Wyatt has started a major new investigation of smart vision sensors. These are analog VLSI systems used for integrated image acquisition and early vision processing. This highly interdisciplinary study utilizes expertise in fabrication technology, circuit theory, circuit design,

system design, vision algorithm design, and parallel computation. The goal of this work is to produce sensor arrays that can be placed at the focal plane of a pair of lenses to acquire binocular image input directly from the environment; with outputs that will consist of the intensity field, velocity field, and depth map of the scene; and with discontinuities in enhanced or extracted fields for separate use as required by the user. Professor Jacob White is developing efficient numerical techniques to solve difficult simulation problems in integrated circuit design and fabrication, as well as approaches that can be used effectively on a parallel computer. Waveform relaxation techniques, originally introduced at the circuit level, are now being successfully applied for device transient analysis as well as the solution of sparse matrices. Professor Jonathan Allen has extended techniques for the production of layout from a circuit schematic with constraints on device size, I/O pin locations, and aspect ratio. In addition, formal grammatical techniques are being introduced for correctness verification of circuit schematics and logic level specifications. A new waveform representation has led to the ability to easily characterize time delay, waveform bounding, and internode noise coupling in a unified way.

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 investigate the relationship between the properties of the acoustic speech signal, the articulatory activity that gives rise to the signal, the auditory representation of the signal, and a linguistic description of the utterance. Mechanisms of sound production at the vocal folds have led to a clear understanding of individual differences in voice quality. New acoustic analyses of vowels and several types of consonants have provided good agreement between theoretical models of sound generation with various source characteristics. Dr. Dennis Klatt has completed several studies of the female voice, as well as the acoustic effects of breathiness, and several source characteristics with a view towards improving the naturalness of text-to-speech synthesis. Principal Research Scientist Dr. Joseph Perkell is acquiring a large amount of data based on a new magnetic recording mechanism that permits the tracking of articulator movements (such as the tongue), which are normally difficult to observe. The long-term goal is to explore aspects of the underlying control mechanisms in order to provide a fundamental basis for speech production. Principal Research Scientist Dr. Victor Zue is continuing a large series of basic phonetic studies aimed at the determination of phonetic features helpful in speech recognition. He is also utilizing a large database of segmented and labeled speech in order to facilitate these studies, and is now beginning to unify many separate studies into an overall framework for a complete speech recognition system.

Perceptual research on hearing and touch is being conducted by Professor Louis Braida, Senior Research Scientist Nathaniel Durlach, and Principal Research Scientist H. Steven Colburn. Fundamental studies of normal and impaired hearing are conducted in order to reveal the limitations of currently available prosthetic aids and to construct new techniques which will provide improved prosthetic function. In addition, several forms of tactile communication are being studied, and a broad viewpoint is being taken toward the formulation of a new program in teleoperators aimed at the development of remote sensory communication systems in all modalities.

In cooperation with the Eaton-Peabody Laboratories at the Massachusetts Eye and 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 Nelson Y.-S. Kiang is conducting studies to understand how single neurons contribute to gross electrical activity at several locations. Professor William Peake, together with Dr. John J. Rosowski, has continued his studies on the middle ear function based on studies in cats, human cadavers, and the middle and inner ear structures of phylogenetically early mammals. These results have led to a new description of the cat's middle ear mechanism over a broader frequency range. Comparative studies show that cadaver ears will be useful for further studies. In addition, similarities have been shown between the middle and inner ear structures of the earliest known mammal and the ears of present-day mice and bats. Professor Thomas Weiss has observed how the cochlea functions to produce nerve messages in response to mechanical inputs. He has achieved new results in the degradation of timing information in the cochlea. In particular, he has shown a low-pass filter mechanism resulting from the electrical properties of the hair cell membrane which limit the rate at which the potential can change across the membrane of these cells. Dr. Donald K. Eddington is conducting several studies on intra-cochlear electrodes in the human auditory system using nine human subjects. He has analyzed both single- and multi-electrode systems, and has achieved a new understanding of the potential distribution within the cochlea caused by such electrical stimulation. In addition to leading to greater knowledge of these prosthetic devices for clinical purposes, these studies also contribute to the understanding of how simple and complex stimuli are encoded at the periphery and interpreted by more central processing capability in normal hearing.

FOCUS AREAS

Atomic, Molecular, and Optical Physics

Professor Shaoul Ezekiel has continued his studies of passive resonator gyroscopes, and is also focusing on new resonance Raman effects that can be utilized as the basis for compact, rugged, and high-accuracy atomic clocks. Professor David Pritchard, using a novel detector comprised of superconducting electronics and a superconducting quantum interference device, has isolated and detected a single nitrogen ion in an electromagnetic trap. This achievement opens a new frontier in mass spectroscopy which is expected to lead to substantial increases in measurement accuracy. He has also obtained the first radio-frequency spectra from atoms confined in a magnetic trap. Through novel ideas for cooling to microkelvin temperatures, techniques for trapped atom frequency standards of unprecedented precision are expected.

Plasma Physics

Professor George Bekefi has introduced very short period micro-wigglers for free-electron laser applications using new high-precision manufacturing technology. Besides their compactness, such systems have the advantage of producing high-frequency radiation within a given electron energy, or conversely, they reduce the electron energy required to access a given wavelength. He has also studied the physics of pre-bunching in a free-electron laser, thus demonstrating a dramatic increase due to pre-bunching in the free-electron laser growth rate. Professor Miklos Porkolab is continuing studies of plasma-wave interactions in purely rf-driven or combined ohmic and rf discharges on the Versator II tokamak. He has shown that the fast wave branch of lower-hybrid waves has the potential of driving current with better efficiency and penetration of hotter and denser plasmas relative to the conventional slow wave approach. The basic ideas proposed by Professor Bruno Coppi for compact ignition devices have received increasing attention in several countries, including the compact ignition tokamak project at Princeton University that is based on the early Ignitor experiment. The Alcator-CMOD device that is being constructed at MIT is also based on earlier theoretical design concepts, combining the favorable confinement characteristics of the Alcator experiments with those of plasma equilibrium configurations having properly elongated cross-sections of the plasma column. The combination of all these characteristics was shown to allow production of stable plasma currents in the multiple mega-ampere range.

Radio Astronomy

Professor Bernard Burke continues to observe the distribution of matter in galaxies and the universe. Ongoing experiments utilize very-large-array and very-long-baseline interferometry techniques to probe several interactions that help to characterize these matter distributions. Professor David Staelin has discovered evidence of atmospheric gravity waves in images obtained from a passive 118-gigahertz spectrometer on a high-altitude aircraft. Further observations are expected to suggest theories for the generation and propagation of these waves and their role in meteorology.

Image Processing

The Advanced Television Research Program (ATRP), led by Professor William Schreiber, seeks to design improved television systems and to provide a forum for the program's sponsors to discuss matters of common interest. Preliminary concepts have been investigated for transmission systems that can provide improved image and sound quality without increased channel capacity. One system is compatible with existing receivers, and can provide improved quality on special receivers. A second system is noncompatible with current receivers, but achieves high definition on one standard channel. Professor Donald Troxel has built the initial software and hardware system architectures for a computer-aided fabrication system designed to integrate computers into the control, data collection, modelling, and scheduling of integrated circuit fabrication processes. Substantial resources have been provided in this system for a variety of novel capabilities, including a personal laboratory notebook facility and an equipment reservation mechanism. This elaborate system provides an on-line, comprehensive view of fabrication processes from process control and innovation standpoints.

Digital Signal Processing

Professor Alan Oppenheim is developing new algorithms which seek to deal effectively with complex signal processing issues, utilizing both numerical and symbolic processing. The basic architecture of knowledge-based signal processing systems evolves from this standpoint. Professor Jae Lim continues to develop high-quality medium-rate speech coding systems, and has recently received very positive responses in subjective ratings. New algorithms and architectures for signal processing is the main focus of Professor Bruce Musicus.

He has developed a new approach for designing fault-tolerant multiprocessing systems for signal processing. He has also built a 16x16 cellular array of bit-serial processors to implement various experimental parallel image processing algorithms. Both projects are expected to lead to applications in many diverse areas.

Electromagnetics

Professor Jin Au Kong is using electromagnetic wave theory in a broad variety of applications. These include microelectronic integrated circuits, microstrip antennas, polarimetric microwave remote sensing, geophysical subsurface probing, and transient electromagnetic pulse propagation and coupling problems. As an example, transient response in the propagation of signals within integrated circuit structures has utilized a combination of the method of characteristics and perturbational series under given circuit parameters to provide fundamental understanding of high-speed interconnect systems.

Communications

Professor Jeffrey Shapiro has furthered theoretical and experimental understanding of the generation, detection, and application of squeezed-state and other nonclassical light beams. He has made the first single-beam atomic vapor squeezing measurement, and has demonstrated the greatest amount of squeezing seen in a Doppler-broadened four-wave mixer. This preliminary result is expected to lead to significant improvements in high signal-to-noise ratio communication systems. Dr. Robert Rediker continues his experiments with an ensemble of five mutually coherent semiconductor diode lasers, remote from and fiber-coupled into an external cavity. In this way, the feasibility of producing lasers based on semiconductors with average kilowatt power has been demonstrated. This is expected to lead to a broad class of applications for this type of laser.

In addition to the focus areas described above, several other research directions have been pursued within RLE. Professor Sow-Hsien Chen has studied the structure and dynamics of colloidal solutions using photon correlation spectroscopy. Using these techniques, he has been able to study the phase transitions of lecithin-water systems, and how these phases can be affected by the addition of urea. Professor Campbell Searle has modelled auditory nerve data to find the basilar membrane parameters which can suggest methods of decoding formant information in speech signals. The characterization of the basilar membrane filtering has indicated that most of the formant information is in the time domain, rather than in the frequency domain of the neural data. Modelling of this filtering is also expected to lead to new techniques for front-end design in speech recognition systems which mimic human capability.

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 university-based 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 Association 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 would do the research and those who would use it. Sea Grant provides funds explicitly for technology transfer.

Last year the Office of Sea Grant awarded MIT \$1.64 million; this was matched by \$1.3 million from industry, the Commonwealth, and MIT. Sea Grant also received more than \$500,000 in related research support from several federal agencies. In all, these funds supported 16 faculty and 22 students from six departments including Civil, Ocean, and Mechanical Engineering, Electrical Engineering and Computer Science, Applied Biological Sciences, 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; coastal processes; living resource utilization, offshore engineering; unmanned underwater systems; and technology development and management for ocean uses. Investigators from other Massachusetts universities participate in some of these research areas. In order to expand its research base, MIT Sea Grant has also initiated several projects through the Marine Center, which are funded jointly by industry and other government agencies. 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 and the Marine Center, *automation in the manufacture of marine systems* has grown into a new theme area for MIT Sea Grant research. Two years of basic research have resulted in 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. Other projects include an effort to accurately transfer geometric data between design and manufacturing systems, supported by the Naval Sea Systems Command; and two projects supported by the Office of Naval Research: development of a computer system to predict and encode 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, a useful tool for automating structural analysis.

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 designing a portable probe to measure volatile pollutants in the field, examining the response of fine sediment to wave action, describing microbial processes that influence the cycling of trace metals in urban estuaries, measuring the

influence of the Merrimack River on Massachusetts Bay, and studying the exchange of toxic organic compounds between sediments and the water column. As part of cleanup efforts, MIT Sea Grant has also been an active participant in the ongoing effort to establish a statewide research and monitoring program focused on Boston Harbor and Massachusetts Bay.

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. The explosive development of biotechnology in recent years has allowed Sea Grant to initiate some exciting studies. Biopolymers from marine sources were used to develop controlled-release drugs, enzyme systems with locally controlled pH, and chitosan-based biosensors. A research team continuing work on shark cartilage achieved purification of an angiogenesis inhibitor with potential for treating tumors; another investigated techniques to use DNA probes as biological monitors of coastal contaminants, such as *E. coli* and other bacteria.

The 1987 Sea Grant Lecture/Seminar, "Health Effects of Omega-3 Fatty Acids: Fish Oil and other Sources," was an important public event. Leading medical, scientific, and legal authorities summarized the exciting but limited scientific evidence available in this field. Other Sea Grant initiatives in the area of marine lipids include a clinical study of the effects of fish oil capsules on atherosclerosis patients; an effort to control lipid oxidation in minced menhaden, a fatty, high-protein fish with potential for human consumption as surimi; and research into a novel biotechnology that seeks to improve aquaculture through controlled release of implanted fish hormones.

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. Towards this end, MIT Sea Grant research in *offshore engineering* includes: a continuing project to use superconducting quantum interference devices (SQUID's) 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 Sea Grant work on theory 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 the Naval Sea Systems Command 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 project seeks to develop models to predict the breaking point and working lives of ropes in a variety of marine applications. One important application is 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. Two projects focus on manipulator control: a viewing camera on the program's remotely operated vehicle (ROV) Sea Grant I is being programmed to watch the manipulator arm, thus improving operator visibility and control; and a powerful new algorithm has been developed that incorporates both sliding and impedance control concepts to provide ROV operators with more robust and dextrous control of manipulators. Another project radically improved acoustic imaging techniques for use in modeling a vehicle's position in the underwater work environment; in tests, remarkable computer images of the sunken USS Monitor were generated from sonar data. A series of projects are developing control systems for autonomous vehicles using a novel hierarchical control architecture developed at the MIT Artificial Intelligence Laboratory. 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 Doherty Foundation, The Perry Foundation, and the Massachusetts Centers of Excellence.

MIT Sea Grant has recently completed arrangements with the National Park Service to use space in the Charlestown Navy Yard at the end of Pier I for launching and field-testing underwater vehicles. A containerized Underwater Work Systems Laboratory will be in full operation by fall 1988.

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 and Marine Computation and Instrument 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.

MIT Sea Grant works to expand its research base by initiating jointly sponsored research through the *Marine Center*. Marine industries and other government agencies provide 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. Current projects include: the development of a small, intelligent autonomous underwater vehicle; an effort to model currents and pollutant transport in Boston Harbor; and basic mathematical research on new methods to represent shape for computer-aided shipbuilding and design.

To encourage the development of new research ideas, Sea Grant sponsors several seed projects annually. Last year a number of diverse projects included 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; work on fabrication and application of double curvature shell structures, and a sampling program to determine disturbance effects of structures on soft offshore sediments.

ADVISORY SERVICES

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

The Sea Grant Collegium, the first collegium on campus, is the program's primary vehicle for technology transfer. Collegium membership 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 welding in shipbuilding and large scale structures, technologies for autonomous underwater vehicle systems, modeling issues for computer-aided design for marine systems, and geotechnical research at MIT.

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. In an effort to observe gear in use at sea, the Center has designed and developed a towed underwater gear observation system (TUGOS). 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. The Saltonstall-Kennedy Fisheries Development Program and Benthos, Inc., the vehicle's builder, have co-sponsored this project.

For the fifth year, the Massachusetts Marine Liaison Service (MMLS) coordinated COASTWEEKS, a statewide celebration that involved over 50 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. MMLS also helped establish a pilot aquaculture facility at Bridgewater State Prison with the Department of Correction. MMLS support for the 1987 Sea Grant Lecture on fish oils resulted in unprecedented media exposure and public interest.

Communications/Information Services added 20 reports to Sea Grant's technical publication 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 500 requests were filled in 1987. 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 Opportunities Program (UROP). In 1987-88, 7 UROP awards were given in the fall semester, 7 in the spring, and 3 in the summer to undergraduates in the Departments of Civil, Ocean, and Mechanical Engineering, Electrical Engineering and Computer Science, Aeronautics and Astronautics, and Earth, Atmospheric and Planetary Science.

The Dean A. Horn Award, established in 1982 to honor the contributions of a former Sea Grant director, was presented to Sandra Lippka, a senior in the Department of Mechanical Engineering, for her design of a handicapped access system for Boston Harbor ferries and cruise boats. MIT has submitted a patent application on behalf of Ms. Lippka and Sea Grant for this research.

Efforts to increase educational opportunities in ocean research were rewarded by the Charles Stark Draper Laboratory, Inc., which provided a graduate fellowship for a student to work on a problem in underwater vehicle design. For the same project, an exchange was arranged with International Submarine Engineering which sent an engineer to provide professional input and an opportunity for interaction with Institute students and faculty.

The Sixth Annual Sea Grant Lecture/Seminar, "Health Effects of Omega-3 Fatty Acids: Fish Oil and Other Sources," was held in October 1987. More than 300 participants heard medical, chemical, and legal experts summarize what is known and still unknown about these promising compounds. Efforts are now under way for the 1988 seminar titled "Automation in the Design and Manufacture of Large Marine Systems."

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 Marcus Karel, Professor in the Department of Chemical 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. New to the staff are John Moore, Jr., Assistant Manager of the Marine Industry Collegium; Karen Hartley, Editor; Thecla Ree, Publications Assistant; Joan Corsaro, Administrative Assistant to the Collegium; and Helen-Marie Quinn, Administrative Assistant to the Director and Executive Officer.

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 1988, Assistant Professor of Ocean Engineering Nicholas M. Patrikalakis was awarded the two-year chair for his work in surface-to-surface intersections, a type of mathematical research with applications in computer-aided design. Continuing to hold the appointment for a second year are Dale G. Karr, Assistant Professor in Ocean Engineering; Jean-Jacques Slotine, Assistant Professor in Mechanical Engineering; and S. Shyam Sunder, Associate Professor in Civil Engineering. To celebrate more than a decade of Doherty support, Sea Grant hosted a dinner in December 1987 for trustees of the Foundation and all current and former recipients of the prize. The significance of this chair to MIT junior faculty was documented in a brochure and presented with thanks to the Doherty Foundation.

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, non-faculty staffing, and all research activities are supervised by faculty members.

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

The Program Director is Professor Fred Moavenzadeh, William E. Leonhard Professor of Engineering 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 following sections of this report summarize the specific activities undertaken by TDP in 1987/88.

CAIRO UNIVERSITY/MIT TECHNOLOGICAL PLANNING PROGRAM

In March 1988 the TDP completed its eleven year, \$29 million program with Cairo University sponsored by the U.S. Agency for International Development. The overall purpose of this program has been to strengthen Egyptian capabilities in science and technology, and to direct these capabilities towards problems of vital importance in Egypt's development. To this end, three specific objectives have been pursued:

- Mobilization of Egyptian academic interest in research on specific development plans and issues;
- Organization of technical research in collaboration with Egyptian government and industry organizations;
- Establishment of an institutional framework under Cairo University auspices capable of conducting similar efforts on a permanent, self-supporting basis.

Prior to the establishment of the Cairo University/MIT Technological Planning Program, very little opportunity had existed for university-based research on development problems in Egypt. Virtually all of the contract research conducted on behalf of the Egyptian government was undertaken by private consultants or foreign experts. Egyptian government officials often had a limited understanding of the methods being used by such consultants, since little effort was being made to upgrade their knowledge of advanced analytical techniques. It was therefore decided by the U.S. Agency for International

Development, Cairo University, and MIT that a program was needed to provide the Egyptian government with access to the resources of Cairo University as a whole, and create suitable incentives for Cairo University faculty members to direct their capabilities toward development-related research.

The strategy used by the CU/MIT Program was to find a broad problem, critical to Egypt's development, which was of mutual interest to MIT faculty members, Cairo University faculty members, and an Egyptian ministry or industrial organization. Over the course of the program, 27 collaborative, multi-disciplinary research projects were undertaken which focused on a broad range of engineering, economic, and social science topics in the following four general subject areas: energy, manufacturing, public works, and socioeconomic development. In addition to demonstrating the feasibility of university-based assistance to the Egyptian government, these projects made significant contributions to the development process in Egypt.

At MIT, 46 faculty members and 100 graduate students from 12 academic departments participated in the research. At Cairo University over 250 faculty members and 200 graduate students were involved, along with 150 professional staff from Egyptian government and industrial organizations. Several hundred other representatives from Egyptian organizations attended program conferences, seminars, workshops, and short courses.

As a result of the CU/MIT Program's accomplishments, the Development Research and Technological Planning Center (DRTPC) has been established at Cairo University, and now provides a permanent institutional mechanism for conducting contract research on development issues with Egyptian ministries, public and private sector companies, and international organizations. Since its inception, over 50 projects have been conducted by the DRTPC on behalf of 34 Egyptian and five international organizations, including the World Bank, the International Labor Organization and the U.S. Agency for International Development. Participating faculty have been drawn from the Cairo University faculties of engineering, science, commerce, political science and economics, and medicine. The research topics successfully investigated by the DRTPC have included:

- Development of an optimum investment policy for maintaining the 4,600 kilometer paved road network in the Delta Region.
- Projecting the future demand for cement in Egypt, and developing appropriate manufacturing and marketing strategies.
- Analyzing various proposed traffic management schemes for the Cairo suburb of Heliopolis, to optimize usage of the existing street network.
- Development of a groundwater simulation model for use in the Western Desert, to predict and evaluate the safe yield of the aquifer system under different groundwater extraction scenarios.
- Investigating the problems caused by flash floods which periodically affect Egyptian cities located near dry river beds, and proposing economically feasible alternatives for flood damage prevention.
- Development of a computerized energy management system for the Egyptian Iron and Steel Company, to assist in monitoring the material and energy balances during various manufacturing processes.

In addition to conducting contract research, the DRTPC has, in collaboration with MIT, organized several academic programs. This educational capability distinguishes the DRTPC from private consulting organizations and many other research centers in Egypt. Over the eleven years of the CU/MIT Program, fellowships were awarded to 87 junior faculty members and graduate students in 25 academic departments at Cairo University to conduct research on specific development topics. Over 370 visits were made to MIT by Egyptian program participants, and twelve advanced degrees were received at MIT by Egyptian students sponsored under the program.

The CU/MIT Program has been widely recognized as an outstanding model for collaboration between front-ranking universities in nations at different stages of development. The overall impact of the program and its value to Cairo University and the Government of Egypt have been highlighted at several international conferences and other meetings. Dr. Mostafa Kamal Helmy, the Egyptian Minister of State for Education and Scientific Research, has referred to the CU/MIT Program as the single most successful joint international scientific venture undertaken by universities representing the U.S. and Egypt; a program which has enabled CU faculty members to become deeply involved in Egyptian developmental problems to an unprecedented extent. Upon receiving an honorary doctorate degree from Cairo University in 1985, MIT President Paul Gray commented on an important result of the program from a broader perspective:

The Development Research and Technological Planning Center represents tangible progress toward the goal of building science and technology into the development process. By bringing advanced research and technology to bear on problems such as energy, manufacturing, transportation, and water resources, the Center is serving as an example and a catalyst for further advancement in this region.

The CU/MIT Program's success was also noted by a team of science and technology experts from the U.S. Agency for International Development, who reached the following conclusion during an evaluation of the program in 1985:

In planning the project it was assumed that it would be possible for interdisciplinary, interorganizational and international project teams to work together to approach practical problems of real importance to Egypt from a sound and sophisticated methodological perspective. This has proved to be true. In fact, given the history of failures of approaches to achieve this goal in other projects, the demonstration of the validity of this premise is one of the key accomplishments of this project.

The TDP considers the most important achievement of the CU/MIT Program to be its demonstration of the value of government/university collaboration and an interdisciplinary approach in the successful application of science and technology to the urgent problems facing countries at all stages of development. The program has also been highly successful in demonstrating the potential for state-of-the-art technologies in countries such as Egypt, as opposed to the more mature or traditional technologies usually utilized in international development programs.

OTHER TDP ACTIVITIES DURING 1987/88

The Middle East Program at MIT completed its second year, under the direction of Professor Nazli Choucri, TDP Associate Director. 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 inter-departmental courses are offered by the program: Politics, Growth, and Development in the Middle East; and Technology, Business, and Public Policy in the Middle East. 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.

A seminar series on "U.S. Policy in the Middle East" was co-sponsored by the TDP and the Center for International Relations at Boston University. Under the direction of Professor Nazli Choucri and former U.S. Ambassador to Egypt Herman Eilts, the series focused on U.S. strategic and diplomatic interests in the region, and how they are affected by the processes of technological, political, and socioeconomic change.

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.

The TDP also entered into discussions with the U.S. Agency for International Development and the University of Engineering and Technology in Lahore, Pakistan concerning potential TDP assistance to that university and to other science and technology institutions in Pakistan.

FRED MOAVENZADEH

Technology Licensing Office

Fiscal year 1988 (FY 1988) continued a trend of significant growth in technology transfer to industry. The Technology Licensing Office (TLO) concluded a record 92 license or option agreements (excluding software end-user agreements). This compares to 65 licenses in FY 1987 and 17 in FY 1986. In terms of number of agreements, we believe our 1988 performance is the highest among all US universities, (last year University of California was first with 68 and Stanford was second with 67). These agreements set the basis for future growth in royalties. Large royalties do not start until the licensee starts manufacturing products. Typically sales of licensed products first occurs two to four years from the date of the license except in the biotech industry where five to eight year product development cycles are common.

Royalties received during FY 1988 were \$2.7 million compared to \$3.1 million in FY 1987. In addition, the TLO accepted shares in ten companies as partial payment of royalties, bringing to fifteen the number of companies in which stock has been taken as partial payment of royalties. This is the first year that equity represents a significant percentage of the TLO's income. All but one of the companies in which the TLO has accepted shares are privately traded. The one exception is publicly traded, but MIT must continue holding those shares because of an FCC ruling. Based on the last trade (most of which were private trades with venture capital companies) the shares brought in by the TLO had a value of \$3.5 million. In future years we will report the change in value from the previous year in TLO stock holdings. Ignoring the stock value, MIT ranks fourth in the US in terms of university royalty income, behind Stanford, University of Wisconsin and University of California (all campuses). If the value of stock is included, MIT's \$6.2 million total income could rank second or third nationally, behind Stanford and possibly University of Wisconsin.

Several new companies have been created around MIT inventions. Eight of the companies started in FY 1988 had first day funding commitments from venture capitalists over \$1 million. These represent many of the largest investments in new start-ups in New England.

In addition to cash royalties and equity, research funding was sometimes a spin-off of a license agreement. Licensees funded approximately \$1.4 million worth of research in FY 1988 directly related to patent licenses.

Several notable developments have occurred with TLO licensees. On the negative side, our largest source of cash royalties is LISP, and many artificial intelligence companies which sell licensed products experienced a serious downturn in business. This downturn was the major cause for cash royalties falling below the FY 1987 number. In addition, TROLL was spun out of MIT, creating a drop in TLO but a net gain to the Institute since expenses within the Institute associated with TROLL activities were also reduced. On the positive side, many of our licensees have started shipping licensed products. Two of our licensees have received regulational approval for diagnosing or treating humans with licensed products. These developments combined with the large number of new license agreements give us reason to believe that royalties will grow significantly in coming years.

The increased activity in the TLO created a need to better understand policy issues related to licensing. The Committee on Patents and Copyrights has been extremely valuable in offering guidance in policy setting as related to the particularly thorny issues. These issues include potential conflicts created through MIT and/or its faculty taking equity in licensees. Other issues addressed in FY 1988 included research funding by licensees, and the standard terms which MIT offers its research sponsors for rights to inventions that result from their sponsorship. The Committee's analysis of these issues has led to numerous refinements in our policy, which create clear guidelines for avoidance of conflict while stimulating the commercial development of MIT inventions and software.

Two changes in personnel have occurred in the TLO during the last year. Ms. Amy Porter has announced her intention to leave her job as Technology Licensing Officer to accept the position of Director of Technology Licensing for Children's Hospital. Ms. Porter has been an outstanding member of our staff and will be sorely missed. Dr. Christina Jansen was hired as Technology Licensing Officer. Dr. Jansen has three degrees in Material Science from MIT and brings more than 15 years of industrial experience to our staff.

JOHN T. PRESTON

Whitaker College of Health Sciences, Technology, and Management

The concept of the Whitaker College derives from the conviction that biomedical problems are complex and require knowledge from a wide range of disciplines for their solution. Since 1983, we have developed areas of research and teaching that are interdisciplinary and at the forefront of medico-biological research, but also an expression of deeply felt needs of the MIT faculty.

Activity in the College is now divided between the Department of Brain and Cognitive Sciences, the Clinical Research Center, and several interdisciplinary programs. I am pleased to report on the events and recent initiatives of our programs in bioengineering, human biology and experimental medicine, and health policy management. The activities of the Department of Brain and Cognitive Sciences and the Clinical Research Center are reported separately.

PROGRAMS IN BIOENGINEERING

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

Biological and Medical Imaging

A new facility has been established for advanced research in the processing and analysis of biological and medical images. Under the direction of Dr. Derek Rowell of the Department of Mechanical Engineering, the facility will serve two purposes: (1) to perform intramural research involving faculty and graduate students on computer-based image manipulation, analysis, and display--including high-level-language image processing and reconstruction methods; and (2) to provide these resources to both intra-MIT and collaborating researchers for the analysis of their images.

The objective is to be able to analyze images from a wide variety of fundamental and clinical data acquisition modalities, including nuclear magnetic resonance; computed tomographic scans; and transmission, scanning, and optical microscopy. Research opportunities will be available in three-dimensional image reconstruction, automated anatomical structure recognition and delineation, image compression of medical images, image enhancement methods, and the development of new imaging methods.

Image acquisition will require microwave or fiber-optic network linkages from a number of source locations, including the Massachusetts General Hospital, the Magnetic Resonance Imaging Facility at the Francis Bitter National Magnet Laboratory, and other locations where biological and medical investigations are conducted. The facility will be networked around three high-performance work stations which will marshal, store, process, reconstruct, and display data from the molecular to the organismic levels in response to the needs and inquiries of staff and students from the College; the Departments of Biology, Brain and Cognitive Sciences, Mechanical Engineering, and Nuclear Engineering; and collaborating extramural investigators. Located on the third floor of the Whitaker College building, facility operations will commence in the fall of 1988.

Drs. Mann and Rowell have been assisted in their efforts to develop a biological and medical imaging program by the College's newest faculty appointment, Dr. Van Wedeen, Assistant Professor. Dr. Wedeen, who holds a joint appointment in the Media Arts and Sciences Center, joined the faculty on October 1, 1987. He is a physician with a background in mathematics who participated in an established research program in cardiovascular flow imaging using magnetic resonance imaging techniques. Current projects also include investigations of the roles in medicine for new methods of three-dimensional spatial visualization such as computed holography and the problem of recording and representing collections of three-dimensional medical data for education and clinical review.

Dr. Gordon L. Brownell, who holds a primary appointment in the Department of Nuclear Engineering, joint with the Whitaker College, continues his studies in imaging using positron tomography at the Massachusetts General Hospital facility. He has been active in the development of new positron imaging devices there, and studies are underway that investigate neural pathways and radiopharmaceutical distribution in mammalian brain on a high-resolution positron tomograph.

Academically, the biological and medical imaging program is tied to a doctoral program in Radiological Sciences. Doctoral 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. Many of the program's students conduct their research and have graduate student offices in the Whitaker College.

technology; radiation biophysics; radiopharmaceutical chemistry; or biological and medical imaging. Many of the program's students conduct their research and have graduate student offices in the Whitaker College. Nineteen students were enrolled in the program this year.

The search continues for new faculty members in areas related to radiological sciences and imaging, with joint appointments in the Department of Nuclear Engineering.

Program in Medicinal Chemistry and Controlled Drug Delivery System

Dr. Robert Langer continues his exciting research on biocompatible and degradable drug delivery systems based on implantable polymers. Dr. Langer, who holds a secondary appointment in the Whitaker College (where his major laboratories are located), will have a primary appointment in the Department of Chemical Engineering, effective July 1, 1988.

Recent Initiatives

This spring, the decision was made to transfer two exciting new interdisciplinary programs to the Whitaker College, effective July 1, 1988. I am pleased to welcome the Program in 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. Thilly is the Director of the Center for Environmental Health Sciences.

PROGRAM IN HUMAN BIOLOGY AND EXPERIMENTAL MEDICINE

Effective July 1, 1987, the primary appointments of Drs. Robert Rosenberg and Monty Krieger were transferred to the Department of Biology. They are maintaining secondary joint appointments in the Whitaker College, where they maintain space and conduct their research.

Dr. Mann and I have begun to explore the possibility of incorporating the study of the effects of combined physical and biological influences on subcellular, cellular, tissue, and organ development in health and disease.

PROGRAM IN HEALTH POLICY MANAGEMENT

As noted in last year's report, the decision has been made to discontinue the program in Health Policy, pending the completion of the degree programs of the eight students currently enrolled. All of the students have passed their qualifying examinations and are working on their dissertations. Examples 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.

Other Activities

Twelve predoctoral fellowships were awarded this spring to students working in the Whitaker College. The funds for these awards, which provide both tuition and stipend over a twelve-month period, are generously provided by the Surdna Foundation, the Edward J. Poitras Fellowship Fund, and the Whitaker Health Sciences Fund.

Our lunchtime seminar series continues. Initiated in 1984, the seminar program convenes several times weekly during the year and has been instrumental in providing a forum for viable exchanges of scientific thought and in promoting a sense of community.

Faculty and Staff

Dr. Gordon L. Brownell was named the recipient of the Coolidge Award of the American Association of Physicists in Medicine. The award is the highest honor given by the AAPM for accomplishment in medical physics. Dr. Brownell was cited for his role in the development of positron imaging, including positron tomography; the development of absorbed fraction dosimetry; and his teaching activities, which include his work in the Radiological Sciences Graduate Program.

EMILIO BIZZI, M.D.
Director

Department of Brain and Cognitive Sciences

This has been a challenging and productive year for the newly formed (July 1986) Department of Brain and Cognitive Sciences. The Department has grown and now includes 29 primary appointments and two joint secondary appointments. Four appointments, two in neurobiology and two in cognitive sciences, began this year.

The purposes in forming and fostering the development of the new department are to integrate MIT's widespread efforts in understanding brain functions, to provide a unified entity to focus Institute and outside support in this area, to encourage collaboration across disciplines, and in particular, to provide the opportunity for comprehensive and multidisciplinary training of young scientists. The Department is part of the Whitaker College. The College, with its focus on interdisciplinary research and education, is ideally suited to encourage and support collaborations across traditional academic disciplines.

The Department is particularly renowned for its strengths in computational neuroscience (visual and motor systems), neurobiology, and cognitive science. Our scope is further broadened by joint appointments and collaborations with the Artificial Intelligence Laboratory, the Department of Biology, the Department of Linguistics and Philosophy, the Department of Mechanical Engineering, and the Media Arts and Sciences Center.

RESEARCH

Research in the Department is structured around four main themes: neurobiology, systems neuroscience, computation, and cognition.

Neurobiology

Neurobiology deals with the biology of neurons, with an emphasis on the special properties of neurons as encoders, transmitters, and processors of information. A detailed understanding of neuronal structure and functions will require application of the techniques and knowledge of contemporary molecular, cellular, and developmental biology. The application of these technologies is leading to exciting studies on the nervous system, which provide new understanding of fundamental mechanisms of brain function. In addition, these studies will have profound clinical implications, in part by generating a framework for the treatment of neurological and psychiatric disorders.

Primary areas of research include the development of neuronal morphology and connectivity, the cellular and molecular basis of behavior in simple neuronal circuits, and neurochemistry and cellular physiology.

Two new appointments have been made in neurobiology this year. Dr. Arthur Lander was appointed to the faculty on July 1, 1987, as Assistant Professor in Molecular Neurobiology. Dr. Lander is interested in the molecular basis of neural development, specifically those molecules involved in the growth and guidance of axons. Dr. Hermann Steller, also an Assistant Professor of Molecular Neurobiology, joined the faculty on September 1, 1987. Dr. Steller's research is concerned with the development of the visual system in Drosophila. Both new appointments are joint with the Department of Biology.

To sum, there are now six faculty members in the Department of Brain and Cognitive Sciences conducting research in neurobiology. There is no doubt that MIT's role in this area has been strengthened by these outstanding appointments.

Systems Neuroscience

Systems neuroscientists in the Department are concerned with vision and motor systems. The scientific aims are to understand transduction and encoding of sensory stimuli into nerve messages, the organization of sensory-motor systems, the processing of sensory-motor information, and the sensory-motor performance of organisms. Sensory-motor research is strongly interdisciplinary and its strength derives, to a great extent, from long-standing research collaborations intra- and inter-departmentally, as well as with other renowned scientists throughout the country and the world. Current research in the Department is conducted by faculty members whose academic disciplines include physiology, psychophysics, computer science and mathematics, and cognitive science.

Computation

In the area of computational neuroscience, the Department's Center for Biological Information Processing serves as a focal point for collaboration between researchers in artificial intelligence, engineering, and

the neurosciences, with the goal of fostering an interdisciplinary approach to the study of information processing in the brain. Computational theories in the area of vision and motor control are developed and tested within the framework of neurophysiological, psychological, and other experimental approaches.

Basic research activities during the past year include the relationships between multiple sensory inputs (e.g., visual, tactile, vestibular) and complex motor output (e.g., eye-head coordination, posture, locomotion, and arm trajectory formation).

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 with 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.

Two new appointments in the Cognitive Sciences were made this year. Dr. Kenneth Wexler was appointed July 1, 1987, as Professor of Psychology and Linguistics. Dr. Wexler is an expert in language acquisition and psycholinguistic theory. In January of 1988, Dr. Michael Jordan joined the faculty as an Assistant Professor of Psychology. Dr. Jordan is pursuing research on skill performance and learning, connectionist models, and speech production.

EDUCATION

Graduate

There were 51 graduate students in the Department this year. The graduate program has been restructured over the last year. The programs of study are designed to prepare students to do original research and to teach. The goal of the program is to train students to be experts in specific research areas and to be well educated in the broader fields of brain or cognitive science. As part of the curriculum, seven new lecture courses have been developed. A brochure outlining our graduate training and highlighting our educational and research opportunities for qualified students was prepared and widely distributed to other institutions this winter. As a result of our efforts in reshaping the Department's educational and research activities, applications for admission in September 1988 increased by 52 percent.

The Department receives predoctoral student support from three training grants from the National Institutes of Health. Our students have also received a number of competitive awards for fellowship funding from the Whitaker College, the Whitaker Health Sciences Fund, and the National Science Foundation.

Undergraduate

The Department has several roles in undergraduate education. It is the home department for the undergraduate major in cognitive science, initiated in September 1982 by interested faculty from the fields of psychology, linguistics, philosophy, and artificial intelligence. In addition, some members of the Department's faculty participate in MIT's new Program in Psychology, which began in September 1987. The program offers undergraduate subjects that fulfill Humanities and Social Science requirements, including the concentration requirement. As a result of faculty interest in UROP, undergraduates have many opportunities to become involved in laboratory research projects in the various fields represented in the Department.

Other Activities

In conjunction with the Whitaker College, the Department continued to offer lunchtime seminars featuring speakers of national and international renown who have presented topics on a variety of subjects related to the disciplines represented in the Department. I am particularly pleased with the level of attendance and the interest and enthusiasm in these seminars.

I am pleased to acknowledge the generosity of the Pew Memorial Trust for support of our program in neurobiology and the Educational Foundation of America for its sponsorship of several interdisciplinary collaborative research projects among faculty in the Department, student fellowships, and our seminar series.

Faculty and Staff

New appointments to the faculty during the academic year include Dr. Kenneth Wexler, Professor; Dr. Arthur Lander, Assistant Professor; Dr. Hermann Steller, Assistant Professor; and Dr. Michael Jordan, Assistant Professor.

Several faculty members have been named as chairholders, effective July 1, 1988.

Dr. Arthur Lander, Edward J. Poitras Assistant Professor in Human Biology and Experimental Medicine.

Dr. Tomaso Poggio, Uncas and Helen Whitaker Professor in Vision Sciences and Biophysics.

Dr. Jeremy Wolfe, Associate Professor, Class of 1922 Career Development Professorship.

Dr. Christopher Atkeson, W. M. Keck Foundation Assistant Professor in Biomedical Engineering.

EMILIO BIZZI, M.D.
Chairman

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 to enable it to take responsibility for all but acutely-ill subjects.

For most of its history, the CRC was administered within a single MIT department, Nutrition and Food Science, (or later, Applied Biological Sciences). Three years ago it became an independent entity within the School of Science, and two years ago it was incorporated within the Whitaker College, reporting to the Head of the Whitaker College, Professor Emilio Bizzi and to Professor Kenneth Smith, Associate Provost and 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 Humans as Experimental Subjects (COUHES), include: professors; research scientists who work exclusively at MIT; and those with primary appointments in local medical institutions, whose research interests overlaps extensively with those of MIT investigators.

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 genetic and other mechanism causing neurodegenerative disorders (like 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 now initiating 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.

Bed utilization at the CRC totaled 2,187 inpatient days. Subjects underwent full-day admissions and there were a total of 896 visits to the CRC's outpatient facilities.

The CRC is administered by a Director, (Professor Richard J. Wurtman), an Associate Director (Dr. William Abend); and five Assistant Directors (Drs. Benjamin Caballero, William H. Dietz, Naomi K. Fukagawa, Robert A. Hoerr, and Dermot A. O'Rourke). Its new facility for Gas Chromatograph Mass Spectrometry is directed by Professor Vernon Young. 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 continues to meet monthly to advise on the operations of the CRC and to review protocols for scientific merit. Four new members have joined the Advisory Committee this past year. They are Professor Richard Held, Drs. Harris Lieberman, Philip Saul and Steven Ziesel. A CRC Governing Body has been constituted; its chairman is Professor Kenneth Smith, and members are Professors Emilio Bizzi, Gene Brown,

John Burke, Arnold Weinberg and Dr. William Dietz. A new Medical Executive Committee oversee all questions relating to subject health and welfare and quality assurance and reports directly to the Governing Body Committee.

The CRC has continued to provide training for physicians who are participating in fellowship programs at MIT. These physicians have utilized the CRC facilities to initiate research protocols and to participate in ongoing projects supervised by senior investigators and faculty. There were five graduate students and 11 postdoctoral fellows from the departments of Applied Biological Sciences, Brain and Cognitive Science, and Whitaker College and MIT's Harvard Division of Health Science and Technology. At the undergraduate level nine Undergraduate Research Opportunities Program (UROP) students participated in clinical research projects with physician preceptors and faculty supervisors.

Two Seminar Series open to the MIT community sponsored by the CRC were held during the academic year. A weekly series in the fall of 1987 was on "Diet and Behavior", and a full-morning symposium in the Spring of 1988 (which was widely covered by the scientific press) dealt with "Tissue Transplantation in the Treatment of Parkinson's Disease".

RESEARCH ACTIVITIES

Nutrition and Metabolism

During the past year the CRC's Nutrition and Metabolism group, directed by Professor Vernon R. Young, have continued to utilize stable isotope tracer probes to explore dynamic aspects of nutrient metabolism in adult subjects of varying age. One major accomplishment has been the finding that the conservation of endogenous methionine at low dietary intakes in healthy adults involves the re-channeling of methionine toward protein synthesis and away from transmethylation (methionine locus) as well as increased recycling of the homocysteine moiety (homocysteine locus). This was accomplished with the aid of a novel dual isotope technique that is now being applied: (a) in a further investigation of the methionine (and cystine) requirement of healthy adults; and (b) to explore the effects of a high dietary methyl group intake on methionine kinetics. Other major findings have been, (a) that glucagon does not have a large effect on the dynamics of amino acid metabolism in peripheral tissues when insulin levels are maintained at "normal" concentrations; (b) further insights are the ways by which the body responds to low leucine intakes; and (c) that zinc and copper absorption in elderly subjects are unaffected by changes in the dietary zinc-to-copper ratio within the physiological range of intakes.

Obesity and Eating Disorders

Dr. William Dietz and his associates have been studying 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 differences in either BMR or TDEE among obese and nonobese adolescents when the results were expressed per kg of fat free mass (FFM). 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.

In another study, Dr. Dietz and his associates compared the thermogenic response to two weeks of carbohydrate overfeeding in six nonobese and seven obese adolescents. BMR, the thermic effect of food (TEF) and TDEE were measured during a maintenance period and during two weeks of overfeeding. BMR and TEF were measured by indirect calorimetry. TDEE was measured by the doubly labeled water method. Blood levels of insulin, thyroid, and norepinephrine (NE) and urinary levels of NE and VMA were measured during the maintenance and overfeeding period. Energy intake was 1.61 x BMR during maintenance and 2.5 x BMR during overfeeding. Increases in BMR were similar in both groups in response to overfeeding. TEF was similar and did not change significantly with overfeeding. TDEE did not increase and did not differ significantly between obese and nonobese in response to overfeeding. The contribution of BMR, TEF, and activity to TDEE was similar in obese and nonobese during overfeeding. Increases in insulin and T3 levels did not differ among the two groups. Plasma and urinary levels of NE and VMA did not differ among the two groups. Plasma and urinary levels of NE and VMA did not change in response to overfeeding. The results suggest: 1) that obese adolescents do not have a reduced thermogenic response to food or overfeeding; 2) facultative thermogenesis does not appear to be a significant factor in the maintenance of energy balance during overfeeding in adolescents.

Dr. Dietz and his group have also been studying body composition and metabolic rate in children and adolescents with cerebral palsy and myelodysplasia. The preliminary data on adolescents with myelodysplasia suggest that metabolic rate is lower than expected when expressed in absolute amounts (kcal/day) but is not reduced when expressed per kg per FFM. These preliminary results suggest that the reduction in metabolic rate observed in this population is due to a decrease in FFM.

It is believed that this result confirms the hypothesis and that testosterone does indeed modulate this aspect of the development of visual cortex. To date the data has not been published. However, this data was reported at the April meeting of the Association for Research in Vision and Ophthalmology.

Neurochemistry - Psychopharmacology

1. Behavioral Studies - Professor Richard J. Wurtman and his associates have used the CRC's behavioral testing resources to examine the behavioral effects of certain food constituents (e.g., caffeine; carbohydrates) and hormones (melatonin). The studies have shown that:

a) Relatively low caffeine doses, - 32-64 mg, or less than the amounts present in a cup of coffee - have easily-measurable effects on vigilance in normal young adults.

b) Administration of exogenous melatonin at a time of day (noon) when the pineal normally is not secreting this hormone can cause feelings of sleepiness in normal young adults. Based on such findings - and on the fact that melatonin secretion normally is initiated shortly before nocturnal sleep onset - it was postulated that the pineal hormone has a role in normal sleep, perhaps sensitizing the brain to endogenous "sleep factors".

c) In the late spring and summer of 1986, a study was begun on the Premenstrual Syndrome (PMS). Since many of the symptoms of this disorder are based on self-reports than direct measurements, they are measuring, on patients, such symptoms such as changes in food intake and changes in diurnal patterns of gonadal hormones; prolactin, and melatonin. Moreover, they are testing the effect of the selective serotonin releasing drug D-fenfluramine on the excessive appetite and mood swings associated with PMS. To date, they have completed a baseline study of the changes in food intake, mood and hormone levels with 10 women who do not suffer from PMS, and have begun to study women who have severe symptoms of this disorder.

2. Studies on the Physiology and Pathophysiology of Melatonin

a) Professor Wurtman and his associates have found that human ovulatory fluids (obtained from subjects undergoing hormonal treatment preparatory to in vitro fertilization, at the Beth Israel Hospital) contain very high melatonin concentrations, - perhaps five times those present concurrently in blood. The source of this melatonin has not yet been identified, but it probably reflects melatonin taken up from the blood stream and perhaps bound to a protein in the follicular fluid. Evidence from laboratory studies suggests that melatonin may have direct effects on ovarian steroidogenesis.

b) Plasma samples taken around the clock from normal (menstruating) women and from subjects with secondary amenorrhea, and find that in the latter group (six or seven patients), melatonin levels during the night and day were about double those in the control subjects. This suggests that the hormone may indeed have effects on ovarian function in humans.

3. Studies on Diseases Associated with Appetitive and Affective Symptoms

a) Drs. Judith Wurtman and Dermot O'Rourke completed a preliminary study on the effects of placebo or a serotonergic drug (D-fenfluramine) on the depressive symptoms, excessive carbohydrate intake, and weight gain of patients with Seasonal Affective Disorder (SAD), - examined in fall/winter, when they were depressed, and in the springtime, when their disease had remitted. We were able to confirm the seriousness of their depression (e.g. using Hamilton Test scores), and their excessive caloric intake; D-fenfluramine was highly effective in treating both sets of symptoms in most of the patients.

b) This same drug was shown to be effective in reducing caloric intake - and in facilitating weight gain amount "carbohydrate-craving" obese people, but only much less so among obese people who do not selectively overeat carbohydrates.

RICHARD J. WURTMAN

Associate Provost for Educational Programs and Policy

Office of the Dean for Undergraduate Education

INTRODUCTION

In the three years since the appointment of MIT's first Dean for Undergraduate Education, the Dean and her staff have focussed on four objectives:

- Achieving a viable and strong Committee on the Undergraduate Program;
- Establishing an Institute-wide sense of attention to and emphasis on the undergraduate academic program;
- Forging from several separate activities a more integrated and identifiable Office of Undergraduate Education to give stronger and often times new support to departmental and faculty teaching enterprises; and
- Providing leadership to an Institute-wide review of the current undergraduate academic program.

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 educational space allocation, renovation, and new construction. Recommendations to the Provost for appointments of faculty to teaching chairs are coordinated to reinforce Institute educational goals. CUP maintains momentum and its trajectory at just the moment when the toughest issues must be broached: ones concerning the first year academic program and ones concerning the balance of general education and degree requirements in science. At the same time, the School of Engineering and School of Humanities and Social Science initiative to launch "contexts" subjects must emerge from differing local visions to an Institute-wide perspective.

The current mission of ODUE is simply stated:

- To address with the academic school deans the obstacles and discouragements faculty and departments identify as impediments to serious dedication to high quality teaching, advising and other forms of interaction with undergraduates.
- To promote a climate of "Why not?" and an excitement for experimentation and possibility.
- To promote and guide Institute-wide review of academic programs, educational content and rationale, balances of emphasis 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 now underway. Quieter efforts and in different formats and schema must also take place, ranging to the individual faculty member -- who must undertake personal internal review of his/her professional dedication and goals within this institution.

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 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 to curricular decisions or to academic legislation. And, both of which are too simple in that they 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 clear that Institute-wide consciousness concerning such fundamental educational issues is high and an eagerness to address them is growing. The next few months will provide that opportunity.

MARGARET L.A. MACVICAR

Committee on the Undergraduate Program

The Committee on the Undergraduate Program (CUP), chaired by the Dean for Undergraduate Education, had an extremely busy year and addressed a number of issues. Significant among them were the following:

- Consideration of IAP in relation to its original goals and new directions it might take. CUP agreed to look at overall calendar issues and endorsed as a two-year experiment: 1) the addition of a spectrum of credit-bearing activities, and 2) a planning and evaluation process for departments and students, particularly freshmen;
- The final report of the School of Science Education Committee;
- Charging a committee, chaired by Professor Kenneth Manning, to examine the first-year program -- in particular, alternative pathways through the first year and the current pass/fail system. The report from the Committee on the First-Year Program was received in June 1988;
- Maintaining close contact with the Science-Engineering Working Group, co-chaired by Professors Robert Silbey and David Wormley, charged with facilitating coordination between the Schools of Engineering and Science in three areas: 1) the relationship between the first-year science and mathematics subjects and the engineering course curricula, 2) the possible need for science offerings beyond the first-year level, and 3) the need for biology education and its introduction into the engineering curricula;
- Charging a subcommittee to review faculty participation in Institute educational and policy activities with a goal of improving the system of equalizing faculty involvement across the five schools.

The Committee heard reports on the following topics: 1) the implementation of the new HASS Distribution Requirement and the optional minor in HASS, both voted by the Faculty in May 1987; 2) adjustments to the Writing Requirement including transferring responsibility for Phase Two to departments; 3) concerns of undergraduate student officers for various educational issues including those outlined in the Report of the Ad Hoc Student Committee on the First Year; 4) the progress of implementing new Context courses; 5) program assessment of Project Athena; and 6) calendar issues raised by the Registrar.

A two-day CUP winter work-session was held in January, focusing on the interrelationships of the General Institute Requirements and the departmental component of the overall four-year program, the intellectual rationale for General Institute Requirements, recognition of education activities in a faculty career, a progress report from the Committee on the First-Year Program, the profile of the admitted class, and reflections from first-year science core instructors. The sessions were well-attended and sparked intense discussion.

During the year, CUP brought together groups of people with varying views on many topics. The Committee synthesized these viewpoints in an attempt to crystallize its agenda for the next 18 months. CUP members agreed there is much to do and expect a full agenda again next year.

Professors Lee Grodzins and Robert Silbey completed their terms, as did student member Nat Seshan. Mr. Michael Behnke, Director of Admissions was a guest of CUP for 1987-88.

LAURA B. MERSKY
Secretary to CUP

THE NEW OPERATIONS OFFICE FOR UNDERGRADUATE EDUCATION: Synthesized in August 1987

Concourse, the Undergraduate Research Opportunities Program (UROP), the Office of the Writing Requirement, and the Office of Curriculum Support comprise the embryonic programmatic arm of the Office of the Dean for Undergraduate Education. With adjacent office space in Building 20, these three offices have integrated into one office.

Still a small office, the Undergraduate Education Office (UEO) currently has seven full and one half-time staff members, including two and one-half support staff. This year, for two different assistant dean positions, we identified extremely strong candidates through the "short list" stage. For one position, we concluded hiring with a non-minority candidate; for the other position, the withdrawal of the minority candidate, our first choice, has led us to reopen the search. In the future, as our office grows, we expect further opportunities to recruit minority staff. UROP is the section of our office most in a position to aid minority student recruitment and retention. Although participation of women in UROP this year reflected exactly the percentage of women at MIT, the percentage of black minority and all minority students was lower than their representation at MIT. We would like to see minority participation grow and will work toward that end. Linkages to Interphase and to IAP may be the key.

The Office of the Dean for Undergraduate Education is represented by staff of its programmatic office on a variety of Institute committees: The Committee on Curriculum, the Committee on Admissions and Financial Aid, the IAP Policy Committee, the R/O Week Advisory Committee, the Colloquium Committee, the Committee on the Writing Requirement, the Undergraduate Student Wage Review Committee, and the Ad Hoc Committee on Course Evaluation.

The sections which follow discuss the major program areas of each section within the Office for Undergraduate Education: Concourse, Curriculum Support, UROP, and the Writing Requirement. Following these summaries is a brief summary of staff activity. This summary includes the educational studies of Professor Benson Snyder, tenured in the Office of the Provost.

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 64 students) and the intimacy the students gain with their professors, tutors and each other with 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.

Sixty-three students enrolled in Concourse for the fall term. Of these, 39 were male, 24 female, 61% and 39% of the total respectively. Twenty of these students (14 male, 6 female) were minority students, 32% of the total enrollment. The spring semester had a total of 43 students, 27 male and 16 female, including in the total 11 minority students (26%).

With regard to academic performance, it is notable that the Concourse Class of 1990 in its sophomore year performed as well as the Class of 1990 on the whole, although the scholastic indices for the Concourse Class of 1990 as entering freshmen were significantly below the mean for the Class of 1990 on the whole.

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 six 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 1987-88 were: Professor Jerome Y. Lettvin, Department of Biology and Department of Electrical Engineering and Computer Science; Professor Robert M. Rose, Department of Materials Science and Engineering; Professor Judah L. Schwartz, School of Engineering; Professor Kenneth R. Manning, Director, MIT Writing Program; Professor Emeritus Irving Kaplan, Department of Nuclear Engineering; Dr. Mangol Bayat, Dr. Thomas Philipp, Michael Crichton, M.D., and William Haas, MIT Writing Program; Dr. Ross L. Finney and David Yavin, Department of Mathematics; Dr. Robert Lourie, Laboratory for Nuclear Science.

Each term ten MIT undergraduates were employed as teaching assistants, to teach, to run evening tutorials and to run recitations in chemistry, calculus, physics and differential equations. We note with sorrow the passing this year of Louise M. Sedlacek, who entered MIT as a Concourse freshman in the fall of 1983, and who subsequently made exceptional contributions to the MIT community and to Concourse as a teacher and friend.

Two completely new and highly successful presentations occurred in the past year. One was Course 21S47, "The Art of Revision," an intensive six-unit writing seminar taught by author and motion picture director Michael Crichton and jointly offered by Concourse and the MIT Writing Program. Crichton, a graduate of Harvard Medical School, is best known for his novels ("Andromeda Strain") and motion pictures ("Westworld," "Coma") but is also the author of three books of non-fiction, a computer program for film production and a computer game. The seminar focused on the writing of non-fiction as a process of revision. Twenty students participated in the seminar, which ran for seven weeks during spring term.

The other new presentation was SP3H2, "Islam and Modernity," a twelve unit Humanities Distribution course, presented during the spring term by Dr. Bayat and Dr. Philipp. This course began 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 complemented perfectly the preceding fall term presentation which dealt with the scientific revolution in the West. We expect to repeat this approach next year.

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, 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. 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. 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.

Collaborative Activities of Math and Physics

This year saw the continuation of the linking of freshman mathematics and physics recitation sections and instructors, a cooperative effort undertaken by the two departments with assistance from our office. Paired recitation sections were populated with a common group of students, and instructors were encouraged to share material and information about their students, visit one another's sections, collaborate on the teaching of the subject matter, and so on. With assistance from the Registrar's Office, linking between recitation sections in 8.01 and 18.01 and between 8.01 and 18.02 was accomplished. Computer scheduling problems at the Registrar's Office were severe and are being addressed for AY 88/89.

In a related vein, we assisted the Physics Department with their effort to address the differences in mathematics preparation of students in 8.01 by assigning 8.01 students to recitation sections based on their enrollment in mathematics. In the spring term we sparked a Physics Department pilot scheduling effort to offer students a choice of different types of recitation sections in 8.02, a concept of offering varied recitation section "flavors" of intellectual approach. This effort will continue in AY 88/89.

In the second term the linking effort between 8.02 and 18.02 included visits of UEO staff to instructors' classes, providing informal critique and feedback about teaching effectiveness, something much appreciated by the instructors involved.

We have found lecturers and recitation instructors to be enthusiastic about the potential of a more integrated freshman year program. A continuing frustration, however, has been the ambivalence of many instructors about spending "extra" time on teaching activities. In our interviews we heard from many how they would like to devote more time collaborating with their colleagues but feel they have not received the proper encouragement to do so. At the same time, compared with our experience of just three years ago, we see evidence of great improvements in attitude, enthusiasm, and interdepartmental communication about freshman year teaching.

The Freshman Interview Project

This was the second year of the Freshman Interview Project, an effort originally connected to our initiative in the mathematics and physics linking collaboration but which has this year come into its own. A working document, "Report on the Freshman Interview Project: Class of 1990," was issued in October and distributed to many faculty and staff members throughout the Institute. Simultaneously, evaluation of the class of 1991 began. Again approximately 50 freshmen and two sophomores from last year's interviews were identified at random and invited to participate in the AY 87-88 year-long interview effort. The interview team consisted of 13 staff volunteers from all the offices active in freshman year related support: UEO, Undergraduate Academic Support Office (UASO), Office of Minority Education (OME), undergraduate offices in humanities, chemistry, mathematics and physics, and admissions, Concourse, the Experimental Studies Group (ESG) and the Integrated Studies Program (ISP).

Context Subject Experiment Coordination and Support

We will soon take on the responsibility of assisting with the CUP-sanctioned experiment on "Human Contexts of Science and Technology," intellectual experiences designed to provide undergraduate students with opportunities to "consider critical questions about the interplay between science and technology and the social, cultural, environmental and economic contexts in which new scientific knowledge and technological applications are pursued." A brochure, "Context Subjects at MIT", has been produced and distributed to all students, and high visibility publicity is planned for the fall. Our challenge will be to inform students and faculty about the exciting new addition to MIT's curriculum at a time when so much else is competing for their attention.

In addition we have begun our role as course manager of the new Context subject "AIDS: Scientific Challenge and Human Challenge," to be offered this fall by Professors David Baltimore and Mary Rowe.

Core Curriculum Group and the Science and Engineering Working Group

UEO continued its responsibility for supporting the regular meetings of the faculty and administrators associated with the freshman program and chaired by Dean of Science Gene M. Brown.

At the request of Deans Brown and Kerrebrock, UEO provides support to the recently charged Science and Engineering Working Group cochaired by Professors Robert Silbey and David Wormley, which is looking at General Institute Requirements in Science, particularly with respect to the science core and distribution subjects.

Data Gathering for Educational Studies

UEO is moving firmly to provide coordination and networking between Institute staff participating in the collection and dissemination of all core subject enrollment and grade information, a data gathering activity that has laid the groundwork for other informal data collection efforts in response to CUP and department inquiries.

We have convened a staff working group as a first step toward an Institute-wide framework for educational studies.

The Undergraduate Research Opportunities Program (UROP) As A Model Program

UROP continues to serve as a model in the growing national interest in undergraduate research. In February MIT was invited to organize a panel, "Launching Lives in Science, the Many Paths of Undergraduate Research," for the annual meeting of the AAAS. In April the Second National Conference on Undergraduate Education took place at the University of North Carolina at Asheville; the dean was the keynote speaker.

Inquiries concerning UROP came from Boston University College of Engineering, the University of Pittsburgh, et. al., and from places as far away as Sweden, Israel and Japan. UROP helped Maharishi International University in Iowa establish a program. Support for undergraduate research came from a diverse number of sources: The Lord Foundation, TRW Corporation, The New England, The National Science Foundation (through the Research Experiences for Undergraduates Program), and Sea Grant.

During the past year an impressive new number of UROP projects in the humanities got underway, helped by the \$50,000 in UROP funds set aside to encourage undergraduate research in areas such as history, literature, and the arts. This effort underscores the priority we give to the Institute-wide deliberations and new directions of academic programs.

UROP participation this year was stable once again with well over half the undergraduate student body participating. The wage rate for directly funded UROP stipends remains at \$5.50 an hour, slightly below the Institute minimum wage of \$5.75, a ratio that has been unchanged for the past two years and will continue into 1988-1989. We expect to waive overhead on approximately the same amount of faculty-sponsored wages in the 1988 fiscal year as in the last, just under \$3,000,000.

The Writing Requirement

With all four undergraduate classes now subject to the Requirement, the numbers of papers processed and evaluated by the Requirement office reached its peak in AY 1987/88. The preparation of the mandated formal Report to the Faculty was a major occupation of this academic year.

Over 300 papers were submitted by seniors in the few weeks preceding the February due date for May. To evaluate these papers more efficiently and more reliably, the Committee held a one-day grading session to which departmental writing coordinators were invited along with regular readers. The session was extremely successful, resulting in 172 papers evaluated in a single day and, at the same time, providing a demonstration to departmental writing coordinators of one effective method to reliably evaluate a large number of papers.

Although almost as many members of the Class of 1988 procrastinated in completing the Requirement as did members of the Class of 1987, there was not the sense of crisis that accompanied the graduation of the first class subject to the Requirement. Seniors who had not completed the Requirement were notified in the summer before their senior year and again at the beginning of January when letters were sent to both their home and campus addresses. Departmental writing coordinators and administrative officers reminded students they needed to fulfill the Requirement. Finally, evaluators for the Requirement and Writing Program staff tutored the few students who had failed the first two submissions of their paper. As a consequence, all of these students finally passed, and in the end, only two seniors failed to receive their degrees because of failure to complete the Requirement.

There was little change between the Class of 1987 and the Class of 1988 in options chosen to complete Phase Two. Last year 53% of the Class of 1987 satisfied Phase Two through a writing cooperative subject, 7% through a writing subject, and 40% by submitting a paper. This year 50% of the Class of 1988 satisfied Phase Two through a writing cooperative subject, 8% through a writing subject, and 42% by submitting a paper.

Writing cooperatives taught by faculty from the Writing Program appear to be not only the most popular but the most effective vehicle for students to complete Phase Two. Indeed, in courses that require mandatory writing cooperative subjects with frequent writing assignments that count as part of the final subject grade, there have been few problems in student completion of Phase Two. The Head of the Writing Program has been actively encouraging the establishment of writing cooperatives in the School of Science, and this year Chemistry, Biology, and Physics have instituted writing cooperative subjects as a regular part of their curriculum. In addition, new writing cooperatives were established in Materials Science and Engineering and in Chemical Engineering, and still more are being sought. Instructors of existing writing cooperative subjects are being encouraged to give students more opportunities to write and to incorporate incentives for good writing into the structure of the subject. Indeed, in subjects where the opportunities for writing and feedback from writing instructors have increased, student writing has improved significantly.

The Writing Requirement's Report to the Faculty

The Writing Requirement Committee's Report to the Faculty was presented to the CUP and the Faculty Policy Committee, then accepted and endorsed by the faculty at its April meeting. The report delineated policies and procedures for the transfer of much of the responsibility for the administration of Phase Two from the Committee on the Writing Requirement to individual departments.

Academic departments will assume primary responsibility for Phase Two in the fall of 1988. The Committee and the faculty have established that students must complete Phase One of the Writing Requirement by the eighth week of the first semester of their sophomore year. Those who fail to do so will have forfeited the paper option, able to employ it only by successfully petitioning the Committee on the Writing Requirement. Approximately 800 sophomores, juniors, and seniors have only until October 14th, 1988 to submit a paper to satisfy Phase One of the Writing Requirement. The Committee decided to begin implementation of the Phase Two completion deadline with the Class of 1990 so that departments would have an additional year to establish appropriate opportunities within their curriculum for completion of Phase Two by the end of a student's junior year.

Having passed on responsibility for Phase Two, we and the Committee on the Writing Requirement will be primarily concerned with quality control and assurance, providing advice and resources to help departments integrate writing instruction into their courses, periodically reviewing implementation plans, and serving as the central repository for data on student Requirement completion.

The Freshman Essay Evaluation

The next academic year will be one of experimentation with the form of the Freshman Essay Evaluation. Instead of having students write one essay from a range of topics, the evaluation will consist of two papers. The first essays will ask students to write a narrative or descriptive essay from a choice of three or four topics and will be used primarily as a measure of sentence-level skills. The second essay will consist of a single prompt: students will be given a scenario of about 500 words concerning some ethical dilemma involving science, or technology, or both; they will then be instructed to argue for a specific course of action based on consideration of the ethical and pragmatic issues involved.

Institute Committee Membership

Ms. Norma McGavern represents Dean MacVicar on the Committee on Undergraduate Admissions and Financial Aid (CUAFA), the Committee on Academic Performance (CAP), and the Writing Requirement. An important curricular issue before the CAP this year was scheduling of evening exams. Discussion and possible resolution of this issue will carry over into the next academic year. Ms. Margaret Richardson represents Dean MacVicar on the Committee on Curricula (COC) and the ROTC Committee. At the request of the COC chair, Ms. Richardson has produced a draft of the COC's policy statement and general guidelines for departments to follow when proposing to offer new subjects. Ms. Jane Sherwin is UEO's representative on the IAP Policy Committee.

The Committee on the Writing Requirement was this year newly headed by Professor Tester of the Department of Chemical Engineering.

Personnel

Staff reporting to the Dean for Undergraduate Education include Professor Benson Snyder who, together with Assistant Dean Margaret Richardson and Program Coordinator Maureen Horgan, directs the Freshman Interview Project, and Ms. Cheryl Butters, Concourse Program Administrator. Director of Concourse Professor Jerome Lettvin has just retired. The new Director is Professor Robert Rose.

Ms. Norma McGavern, Associate Director of UROP, is also Acting Head of the Undergraduate Education Office. Program Coordinator Maureen Horgan has worked with Assistant Dean for Curriculum Support Margaret Richardson on a variety of projects while keeping a hand in with UROP as well.

Ms. Richardson returned from a maternity leave in September, returning to work 60% of full time. Ms. Horgan became a full time staff member in September.

Ms. Bonnie Walters, Coordinator of the Writing Requirement since its beginning some five years ago, moved to the Undergraduate Academic Support Office and became Assistant Dean there in October. Following a lengthy and productive search Dr. Leslie Perelman was hired as Assistant Dean in December to coordinate the Writing Requirement.

A loss to the UEO was Ms. Pamela Laufenberg who left MIT this spring to move to Binghamton, New York. Ms. Dianne Brooks, Administrative Staff Assistant, has taken on for the first time the assignment of producing the UROP Directory. She has also been appointed to the ad hoc Institute Committee on Family and Work after having served as a member of the Working Group on Support Staff Issues this past year. A small army of student office assistants have provided important support to the office throughout the year: Teresa Lyons, '90, Wendy Park, '91, Angeli Salgado, '89, Kris Sheahan, '89, and Corinne Wayshak, '89. Computer consultant Jae Sang, '89, found and trained an apprentice consultant, James Dailey, '90, who will be working on his first major project for the office in the summer of 1988.

We were fortunate to have had as temporary office staff assistant Ms. Julia Ryan. Ms. Laurie Sokolosky's aid has been valuable when we needed graphic design work and photography. Mr. Sean Cullen has provided analysis of freshmen interview data.

Mr. Greg Smith, Special Projects Coordinator, who has visited students involved in UROP projects, taken photographs, and worked on academic midway during R/O week for UROP, has retired from regular involvement. He has been an active volunteer staff member since the early 1970's.

We were saddened to learn of the death of Ms. Amy Blue, the first UROP staff member, and Associate Director of UROP in 1971 and 1972. Most recently, Ms. Blue was Associate Vice President for administrative services and facilities at Stanford University.

NORMA MCGAVERN

DIANNE BROOKS	MARGARET S. RICHARDSON
CHERYL BUTTERS	ROBERT M. ROSE
MAUREEN A. HORGAN	JANE SHERWIN
PAMELA LAUFENBERG	GREGORY SMITH
JEROME Y. LETTVIN	BENSON SNYDER
LESLIE PERELMAN	BONNIE J. WALTERS

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

Professor Robert MacMaster chaired this standing committee in R.O.T.C. There was an especially fruitful series of conversations, prompted by the release of the summer 1987 Report on ROTC Issues prepared by a sub-committee of the faculty Committee on Student Affairs. In order to address the issues raised and to look toward a better serving oversight mechanism for the ROTC programs, an ad hoc working group will be established by the Dean, with the enthusiastic support of the standing committee.

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 1988 was as follows:

	FRESHMEN	SOPHOMORES	JUNIORS	SENIORS	TOTAL
MIT	28	32	27	21	108
HARVARD	5	2	5	1	13
TUFTS	6	1	4	8	19
WELLESLEY	<u>3</u>	<u>1</u>	<u>0</u>	<u>1</u>	<u>5</u>
Total	42	36	36	31	145

Besides providing opportunities for the development of leadership skills, the AFROTC program provided MIT cadets with over \$1.2 million for tuition. Cadets from the other schools received tuition payments exceeding \$.4 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 organization of AFROTC cadets, hosted the 1988 national conclave for AAS with over 1700 cadets from nationwide attending. Other events included the Annual Tri-Service Awards Banquet, the Military Ball, Field Day, and the Annual Tri-Service Pass-in-Review. The year concluded with the traditional commissioning at the USS Constitution.

Twenty-four senior cadets received commissions as second lieutenants in the Air Force. One of these chose to fulfill his military commitment in the Reserves. Two lieutenants will go on to pilot training, and one will attend medical school.

Colonel Gary G. Nelson, AFROTC Detachment Commander, completed his first year of dedicated service at MIT. Additionally, Captain Ray Levias and Captain Charles D. Barondes were assigned to this detachment. Major Simeon B. Tubig, Major Douglas L. Loverro, and Captain Randy L. Bliss departed.

COLONEL GARY G. NELSON, USAF

Army ROTC

The 1987-88 Academic Year continued to be productive for the Army Reserve Officers' Training Corps (ROTC) Program. Overall enrollment was maintained at a good high level. Over the academic year, a total of 95 students participated in our program, and at year's end, 87 of those students were still enrolled. MIT student participation showed a slight decrease from 54 to 48 during the year, while Tufts increased from 12 to 17. We are particularly gratified at the quality freshmen enrollment, and look forward to the continuation of this upward trend. Our emphasis on freshmen awareness of Army ROTC showed a high payoff in 1987-88. Fourteen freshmen applied for Army scholarships. Four were offered three-year scholarships, and nine received an offer of a two-year scholarship (for their junior and senior years).

A breakout of year-end enrollment by year and institution as shown below.

	FRESHMEN	SOPHOMORES	JUNIORS	SENIORS	TOTALS
MIT	11	13	15	9	48
HARVARD	2	8	2	4	16
TUFTS	8	4	3	2	17
WELLESLEY	0	5	1	0	6
	21	30	21	15	87

Of the 48 MIT students enrolled, 33 are currently recipients of Army ROTC scholarships and eight others have applied. Current scholarships pay full tuition, a monthly allowance of \$100.00, and a once a year textbook allowance of \$370.00. The value of these scholarships to MIT for school year 1987-1988 was \$422,895.00. We anticipate that for school year 1988-89, approximately 39 MIT cadets will be on scholarship with a value to MIT of approximately \$555,049.00. New scholarship winners announced after March 1988 will receive payment for 80% of their tuition, plus the same allowances.

This year the Army ROTC Department commissioned 14 new second lieutenants, 9 of whom were from MIT. Of the 14, one is entering medical school, four will be reporting immediately to active duty, five are serving in the Army Reserve, two are obtaining their Master's Degrees, and two others are awaiting word on their requests for active duty. We were short of meeting our commissioning mission from our higher headquarters of 18, but expect to be successful for school year 1988-89.

During the year, Army ROTC again sponsored the Annual Tri-Service Awards Banquet with over 125 cadets receiving awards from 45 different organizations. Vice President Simonides and several other MIT representatives, along with the Dean of Harvard College and representatives of the Tufts and Wellesley administrations, attended the banquet. The guest speaker was General Gray, Commandant of the Marine Corps, who discussed some of the challenges facing ROTC graduates. Army ROTC also participated in various Tri-Service events sponsored by the other services such as the Military Ball, Field Day, other athletic competitions, the Annual Tri-Service Pass and Review and Parade, and the Tri-Service Commissioning Ceremony at the USS Constitution.

On and off campus learning experiences continued to be expanded this year as cadets were given the opportunity to train on more Army weapons systems, were familiarized with more "state-of-the-art" systems, and were again flown in Army UH-1 helicopters. This year the flight was on return from a weekend of training at Fort Devens, Massachusetts, to the Athletic Field at Tufts University. We were met by an interesting group of some eighty spectators, about half chanting pro-ROTC slogans and half chanting anti-ROTC slogans.

The ROTC Faculty Committee, under the chairmanship of Professor Robert MacMaster, 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 27 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.

Of the eight military members of the Army ROTC staff, there were three departures since last year and two new arrivals. I have found this second year of mine as a member of the staff to be rewarding, challenging, and exciting. I look forward to the continued development of this strong and vital program.

LIEUTENANT COLONEL EDWARD D. HAMMOND, ARMY ROTC

Navy ROTC

1. Student enrollment for the 1987-88 school year was:

Total - 195 (172 men; 23 women)

Seniors - 41 (including 13 Harvard; 5 Tufts; 5 on fifth year leave of absence)

Juniors - 37 (including 7 Harvard; 2 Tufts)

Sophomores - 45 (including 11 Harvard; 11 Tufts)

Freshmen - 72 (including 20 Harvard; 11 Tufts; 10 are non-scholarship college program, 62 are on scholarship)

All the sophomores, juniors and seniors are on scholarship.

2. On 26 May, 22 men and 2 women were commissioned as officers in the United States Navy and Marine Corps at a Tri-service ceremony in USS CONSTITUTION. Additionally, on 8 June, 8 men and 3 women were commissioned at a separate ceremony for Harvard graduates. The assignments for these officers were:

Surface Line	- 9	Medical Service Corps	- 2
Submarines	- 8	Civil Engineering Corps	- 1
Naval Aviation	- 7	Supply Corps	- 1
Marine Corps	- 5	Engineering Duty	- 1
Special Warfare	- 1		

Also commissioned were three in January, and three anticipate summer commissioning.

3. Captain Robert W. Sherer relieved Commander James G. Ward as Commanding Officer and Visiting Professor of Naval Science. Commander Ward resumed the position of Executive Officer.

4. Lieutenant Charles R. Souter (MIT '83) was killed in an automobile accident in May. He will be sorely missed.

5. Increased emphasis was placed on the sailing program utilizing the 41' Navy Sailing Yacht PATRIOT resulting in more hours underway and more crew qualifications than in the past.

6. Other highlights of the year include:

- a. An 11 day August orientation for incoming freshmen at Fort Devens (Ayer, MA).
- b. Field trips to South Weymouth Naval Air Station, and the Naval Education Training Center, Newport, Rhode Island.
- c. Visits by senior military officers including General A. M. Gray, Commandant of the Marine Corps. General Gray spoke at the Tri-service Awards Banquet.
- d. Assignment of three midshipmen to foreign exchange cruises with Japan and Korea
- e. Successful completion of a Command Inspection by the Chief of Naval Education and Training Inspector General.

7. Personnel changes:

Lieutenant Michael J. Quinlan relieving Lieutenant Brunson in August 88 as instructor for two courses:

- Naval Ship Systems
- Seapower and Maritime Affairs

Lieutenant (junior grade) David C. Hovda assuming Lieutenant Souter's duties in July 88 as Navigation Instructor.

Gunnery Sergeant William Dubose relieving Gunnery Sergeant Laboy in August 88 as Military Instructor.

Kyoko Bass joined the staff as secretary in May 88.

Kristen Adams joined the staff as receptionist in July 88.

CAPTAIN R. W. SHERER, U.S. NAVY

Office of the Dean of the Graduate School

The Annual Report of the Dean of the Graduate School (DGS) appears in two parts. The first is a pair of narrative reports by the Dean and Associate Dean. The second is a set of tables of statistical information for the Graduate School. These are presented in formats similar to those used in past years in order to facilitate comparisons over time.

DEAN OF THE GRADUATE SCHOOL

Implementation of the Tax Reform Act of 1986, as applied to graduate students, began in earnest during the past year. Although the Act became effective on January 1, 1988, we were able to make use of its grandfathering provisions to delay taxation of the majority of our graduate students until the beginning of our new fiscal year on July 1, 1988. Under provisions of the Act, the stipend of graduate research assistants became subject to federal income tax for the first time, as did that portion of fellowship awards in excess of tuition and direct educational expenses. The stipend of graduate teaching assistants was in most cases already subject to federal income tax and was, therefore, not affected by the new tax law. Implementation was complicated by the continued absence of formal Internal Revenue Service (IRS) rules and regulations throughout the past year. However, working with the MIT Payroll Office and tax counsel, we were able to establish a set of operating principles which we believed to be consistent and defensible. These principles were enunciated in two memoranda which were distributed to all graduate students and administrative offices throughout the Institute. The Office of the Dean of the Graduate School (ODGS) quickly became a focal point for information regarding the new tax law and its applicability to graduate students. During the past year the ODGS received literally hundreds of inquiries from within MIT, and dozens of calls from other universities across the United States seeking guidance on their implementation plans.

Of particular concern was the applicability of the new tax law to international students. Under the new law, US and permanent resident recipients of fellowships had no tax withheld from their awards even though a portion of it might be taxable income. In contrast, nonresident alien students receiving fellowship support were subject to withholding at a fixed rate of 14 percent. Many nonresident aliens were, however, eligible to eliminate some or all of this tax burden through the provisions of tax treaties which had previously been established between their home country and the US. Similarly, some students supported as research or teaching assistants were also found to be eligible for tax exemption under relevant treaty provisions. With the assistance of tax counsel, the ODGS prepared a document summarizing the provisions of US tax treaties with 36 foreign countries along with instructions on applying for the relevant tax exemptions. This document was distributed to all nonresident alien graduate students at MIT.

The ODGS was also involved in implementation of the Immigration Reform and Control Act of 1986 (IRCA). This Act directly affects all graduate students at MIT who are employed by the Institute in any capacity, and requires that their employability be verified by examination of various documents. Since the number of students requiring such verification during the past year numbered approximately 3,000, responsibility for implementation of the verification and certification process was eventually delegated to the individual departments.

In each of the last two annual reports, attention was directed to the continued growth of our graduate student population. Graduate student enrollment had grown in all but four of the last 25 years, had grown at annual rates of nearly three percent in several recent years, and appeared ready to exceed a level of 5,000 regular students in the near future. However, explicit and aggressive efforts to control graduate student enrollments in the School of Engineering, and to a lesser extent in the Sloan School of Management and in the School of Urban Studies and Planning, produced an enrollment reduction of nearly three percent (a decline of 147 students from last year's high of 4979 graduate students; see Table I). This decrease in graduate enrollment has occurred at a time when the Institute is concerned about potential decreases in federal research support and has adopted limits on faculty and staff growth in a number of areas.

The number of Master's degrees awarded in the past year declined by more than eight percent (a decline of 94 Masters degrees from last year's figure of 1150; see Table II). This decline is probably related to the enrollment drop cited in the preceding paragraph because a substantial majority of the Institute's Masters degrees are awarded in the three schools where that enrollment drop was concentrated. At the same time, the number of doctorates awarded in the past year increased by nearly 13 percent (see Table II), reflecting, perhaps, the longer time lag between enrollment changes and completion of doctoral programs.

While studying enrollment trends during the past year, it was noted that the enrollment increases of recent years could not be explained in terms of increased admission of graduate students. In fact, in some years where the admission of new students declined, the total enrollment of graduate students still increased. These observations suggested that the average length of time spent by students in our graduate programs must be increasing, and prompted an analysis of the length of time required for completion of graduate degrees at MIT. The necessary data were assembled and subjected to a preliminary analysis just prior to completion of the past academic year. The initial results are clear. In the past decade, the time to completion of the doctoral degree has increased in every department at MIT, with the average increase being in the order of three-quarters of a year. Ten years ago the average time to completion of the doctorate was just over four and one-half years; now the average has grown to almost five and one-half years. Similar trends have been reported at many other institutions in the US. A smaller but consistent pattern of increases was noted in data for time to completion of Masters degrees at MIT as well. During the next year we plan to analyze these data in more depth, and meet with department heads and other faculty to see if the present trends can and should be reversed.

Another issue of some concern to the ODGS is the stagnated level of women graduate students at MIT. That level has fluctuated between 18 and 21 percent throughout the 1980's (see Table VIII) and shows no sign of increasing. Worse yet, the stagnation is observed not only in the total enrollment, but also in the figures for enrollment of new students. Admissions statistics for the past year hint at a possible change for the future (eight percent decline in male applicants and a three percent increase in female applicants; see Table IX); however, it is premature to draw any real conclusions from these data. Rather, we must conclude that an as yet unresolved problem exists and hope that positive steps can be taken by individual departments and the ODGS for future improvements. Issues related to the status of minority graduate students at MIT are discussed by Associate Dean John B. Turner in a separate section of this report.

A decision to close the Department of Applied Biological Sciences at year's end created an unexpected and unusual challenge for the ODGS. At the Provost's request, Dean Perkins chaired a special faculty committee which was charged with expeditious resolution of the many practical problems facing the department's graduate students as a result of the department's impending closure. The committee held a number of meetings throughout the spring term, including one open meeting with a majority of the department's graduate students, and was able to establish principles and procedures for dealing with most of the problems which were identified. In particular, arrangements were made for current students to continue their degree programs, for the continuation of an administrative office for these students, and for the maintenance of graduate assistant support levels of students whose advisors have moved to new departments where lower support levels obtain. As yet unresolved is the future of the department's interdepartmental biochemical engineering degree program.

The Committee on Graduate School Policy (CGSP) carried out its usual academic review functions at the end of each term by reviewing grades, issuing academic warnings where appropriate, terminating the registration of several students whose performance was satisfactory, and recommending candidates for advanced degrees. The CGSP also reviewed a number of proposals for new programs, and gave approval to the following:

- (1) Experimental Masters degree program in the Department of Electrical Engineering and Computer Science.
- (2) Masters degree to be awarded by the Joint MIT-Woods Hole Oceanographic Institute Program.
- (3) Masters degree program in Health Sciences and Technology for HST/MD students.
- (4) Masters degree program in the Leaders for Manufacturing Program.
- (5) Doctoral program in History and Social Study of Science and Technology offered jointly by the Program in Science, Technology and Society, and the faculties of History and Anthropology.
- (6) Interdepartmental program in Building Technology.

The CGSP also reviewed its policies concerning supplementation of graduate assistant stipends, pro-ration of stipends and tuition charges for students who complete their degrees early, criteria for completion of theses, and fellowships which offer cost-of-education allowances in lieu of tuition.

The ODGS continued to interact in positive ways with the Graduate School Council (GSC). The GSC's statement of Graduate Student Rights and Responsibilities appeared for the first time in this past year's edition of the Graduate School Manual, and has been used on a number of occasions as a basis for counsel and conflict resolution. The GSC and ODGS worked particularly closely to establish the principle that graduate research assistants have a right to know the sources and nature of their research support. An initiative of the GSC also led to the establishment of a regular series of luncheon meetings with the ODGS staff and departmental graduate administrators. These meetings have been instrumental in increasing the level of communication on graduate student matters during the past year. Hannah D. Roberts, graduate administrator in the Department of Biology, was particularly helpful in organizing these meetings.

The ODGS continued to operate throughout the past year under severe staffing constraints. Associate Dean Jeanne E. Richard was absent for the entire year due to continued illness and was placed on long-term disability at year's end. Dean Richard's experience and knowledge of Institute procedures will be missed. Two long-term support staff members of the ODGS, Linda G. Peterson and Jean M. Frank, also left in mid-year for new positions. The administrative disaster which could have resulted from these personnel changes was avoided thanks to the yeoman efforts of the remaining staff. Recognition is due Jackie A. Sciacca, Assistant to the DGS, who carried a major portion of three positions throughout the spring term, and to Chris R. Palmer, who successfully handled many additional duties.

Near year's end, Associate Dean John B. Turner, announced that he would be stepping down from his position early in the coming year. Dean Turner's 14 years of experience in the ODGS, and his tremendous successes in the area of minority graduate student recruiting and support have won for him a special place in MIT's recent history. In response to his and Dean Richard's departures, a decision was made to restructure the ODGS. The current structure, which involves two associate deans and an administrative assistant, will be replaced by a single associate dean and two assistant deans. The first step toward implementation of this new structure was taken at year's end with the appointment of Dr. Isaac M. Colbert, an 11-year employee of MIT, as the new associate dean. Dr. Colbert's first assignment will be to direct implementation of the new ODGS structure.

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. Those terminating their service this year and their replacements are:

- Materials Science and Engineering
Professor John Vandersande replaced by Professor Samuel Allen
- Ocean Engineering
Professor T. Francis Ogilvie replaced by Professor Henrik Schmidt
- Political Science
Professor Harvey M. Sapolsky replaced by Professor Nazli Choucri
- Linguistics & Philosophy
Professor Paul Horwich replaced by Professor Sylvain Bromberger

FRANK E. PERKINS

Unlike many of its sister institutions around the country, MIT experienced an increase in its enrollment of underrepresented minority group students (Black Americans, Hispanics, and American Indians) for the fall of 1987-88. The increase was slight (1.3%) going from a total of 146 in 1986 to 148 in 1987. Although the numbers are not staggering, we are pleased to see a positive slope in minority graduate student enrollment at the Institute. The positive slope is primarily bolstered by the fact that we had a 29% increase in the number of first-year minority graduate students who enrolled in 1987 compared to 1986. The Department of Urban Studies and Planning made the largest contribution to the newly admitted class by enrolling three times as many minority graduate students for the fall of 1987 as they did in 1986. This feat is mainly attributable to two factors: (1) A new minority fellowship program that provided 12 fully-funded fellowships (tuition plus \$5,000 stipend). Funds for the fellowships

were provided by MIT. (2) An aggressive departmental recruitment program that was coordinated by Mr. Thomas Stokes, Minority Recruiter for the Department. It is hoped that other departments will follow the lead of the Urban Studies and Planning Department and design imaginative and aggressive recruitment programs to attract more underrepresented minority graduate students.

We are especially concerned about the extremely low number of minority applicants to the School of Science. From all six Departments in the School of Science, a total of only 29 minority students applied to graduate school, with only 14 being admitted and eventually six enrolling for 1987. Even though we sent out a number of people to recruit new students, we are not getting the minority applicants in biology, chemistry, mathematics, physics and earth and planetary sciences. Colleagues at other graduate schools report that minority students are not applying in the sciences at their institutions either. The problem nationally is that there is an extremely low to non-existent "pool" of minority applicants. An insufficient number of underrepresented minorities are receiving bachelors' degrees in the biological and natural sciences to supply our graduate and professional schools.

To combat this problem of a low pool of minority science students with bachelors' degrees, MIT through the Graduate School Office decided in 1986 to "grow" its own pool by creating an early identification program that would reach students in the sophomore and junior years of their undergraduate study and give them "hands-on" experience in a research environment for 10 weeks during the summer. These students work side-by-side with MIT faculty, graduate students and postdoctoral students to learn first-hand what a chemist or biologist does in a real-world setting. The summer of 1988 will be the third year for this program, and the early results are most encouraging. We started with 8 students in a pilot program in 1986, increased to 12 in 1987, and there are 16 students coming to the summer program in 1988. We had over 80 students apply to the 1988 program; all of the applicants had well over 3.0 GPA's out of a possible 4.0. MIT has already benefited program by having three of the program's graduates enroll in our graduate school. All of the program's graduates have gone on to post baccalaureate academic work.

MIT's Minority Summer Science Research Program was aided by support from Dean Frank Perkins in the Graduate School Office and Dean Gene Brown of the School of Science. We also received financial support through a grant from the National Science Foundation as well as funds from the Carnegie Corporation of New York, Dow Chemical Foundation, Proctor and Gamble, Honeywell, and Pfizer Company. We hope to expand the minority summer program in the future with respect to size and fields of study.

1987-88 was a very good year for the Black Graduate Student Association (BGSA). They had exceptional leadership in the person of Mr. Bernard Loyd, Chairperson of the organization. The BGSA with the support of the Dean of the Graduate School Office sponsored a number of activities at the Institute that were designed to make the adjustment of minority graduate students to MIT as smooth and enjoyable as possible while at the same time making their events and activities attractive to the larger MIT community. Some of these activities included the Minority Graduate Student Orientation Program; BGSA/BSU Roundtable Discussions; Talbot House Retreat in Vermont; publication of a 61-page Minority Graduate Student Guide; Minority Graduate Student/Faculty Reception; Black Graduate Coalition Reception held in concert with Harvard, Boston University, Northeastern, Tufts and Brandeis Universities; Pot-luck Dinners; publication of monthly newsletter; T-shirt sale; and a canoe trip on the Sudbury River. Of special note was the Ebony Affair Dance which attracted more than 500 people and which featured the recording group, "Pieces of a Dream", a fashion show, an African Motif Party and cuisine, as well as a jazz quartet from the Berklee College of Music.

The BGSA was finally able to realize one of its long-held goals -- to identify space on campus for a permanent base, a home. The Institute allocated space in Walker Memorial Hall on the third floor as the new home of the BGSA, Room 50-304. Through the industrious efforts of several helpful people, the "squirrel" room was converted into an efficient, well-appointed (computer system and printer, stereo, microwave oven, refrigerator and comfortable furniture) office and lounge. The BGSA subsequently named their new quarters, "The Dean Turner Lounge" in honor of their advisor and founder, Dean John B. Turner of the Graduate School Office.

MIT has come a long way from 1968, when only 16 minority graduate students were enrolled in its graduate school, to 20 years later when it has over 9 times that number (148). Over the past 14 years MIT has produced over 500 minority graduate students with master's degrees and over 113 minority Ph.D.'s. Even though we have made a "start"

toward expanding the diversity of MIT at the graduate level, minority graduate students still only represent 3% of the total graduate enrollment while they represent approximately 15% of the U.S. population. We have not reached parity yet and cannot relent in our efforts to attract more underrepresented minority graduate students to MIT.

JOHN B. TURNER

TABLE I

REGULAR GRADUATE STUDENT ENROLLMENT - FALL TERM 1987

(Numbers in parentheses indicate the change from Fall Term 1986)

	Foreign	Women ⁽¹⁾	Minority ⁽²⁾	Total	Non-Resident ⁽³⁾
School of Architecture and Planning	135(-21)	145(-13)	24(+1)	444(-14)	42(+1)
School of Engineering	708(-66)	324(+4)	58(-4)	2280(-123)	7(-21)
School of Humanities and Social Science ⁽⁴⁾	117(+10)	89(-18)	8(-2)	355(-3)	53(-26)
Sloan School of Management	175(+8)	88(-28)	19(-1)	555(-33)	6(-5)
School of Science	294(+10)	262(-5)	27(NC)	1112(+15)	3(-13)
Whitaker College	9(+3)	15(NC)	1(-1)	57(+5)	0(NC)
Health Science & Technology	3(NC)	6(+2)	1(+1)	29(+6)	0(NC)
TOTAL	1441(-56)	929(-58)	138(-6)	4832(-147)	111(-64)

(1) See also Table VII.

(2) Includes Black Americans, Puerto Ricans, Mexican Americans, and American Indians.

(3) Included in Totals.

TABLE II

GRADUATE DEGREES AWARDED: 1987-88

Advanced Degrees Conferred	M.C.P. M. Arch	S.M.	Engineer	Sc.D.	Ph.D.	Total
September 1987	4(-2)	173(-11)	5(+2)	16(+7)	91(-7)	302(-1)
Woods Hole			2(+2)	4(+4)	7(+4)	
February 1988	12(-4)	200(-26)	17(+4)	10(-6)	156(+12)	399(-22)
Woods Hole			0(NC)	0(-1)	4(-1)	
June 1988	51(-8)	615(-44)	24(-2)	17(NC)	202(+37)	922(-5)
Woods Hole		1(+1)	1(+1)	0(NC)	11(+10)	
TOTAL	67(-14)	989(-80)	49(+7)	47(+4)	471(+55)	1623(-28)

Numbers in parentheses indicate change from 1986-87 to 1987-88.

TABLE III

DOCTORAL DEGREES AWARDED EACH YEAR BY SCHOOL AND CITIZENSHIP

Each number is the total of the doctoral degrees awarded in September, February and June of the academic year indicated. The numbers in parentheses are the number of degrees awarded divided by the corresponding regular graduate student enrollment (5th week count).

Academic Year		Arch.	Eng'g.	Hum. and Soc. Sci.	Sloan	Science	HST	Whitaker College	Total
1978-79	Citizen	10(.0431)	80(.066)	35(.164)	10(.035)	126(.151)			261(.093)
	Foreign	<u>3(.033)</u>	<u>64(.101)</u>	<u>11(.130)</u>	<u>9(.088)</u>	<u>33(.142)</u>			<u>120(.105)</u>
		13	144	46	19	159			381
1979-80	Citizen	8(.031)	96(.074)	40(.156)	5(.017)	127(.153)			276(.094)
	Foreign	<u>3(.034)</u>	<u>66(.096)</u>	<u>11(.109)</u>	<u>3(.029)</u>	<u>28(.115)</u>			<u>111(.091)</u>
		11	162	51	8	155			387
1980-81	Citizen	12(.044)	88(.065)	40(.178)	7(.022)	118(.138)			265(.088)
	Foreign	<u>7(.078)</u>	<u>75(.103)</u>	<u>12(.153)</u>	<u>2(.020)</u>	<u>35(.130)</u>			<u>131(.104)</u>
		19	163	52	9	153			396
1981-82	Citizen	7(.023)	94(.066)	35(.128)	4(.012)	124(.148)			264(.083)
	Foreign	<u>2(.017)</u>	<u>75(.104)</u>	<u>21(.223)</u>	<u>6(.050)</u>	<u>35(.123)</u>			<u>139(.103)</u>
		9	169	56	10	159			403
1982-83	Citizen	6(.026)	93(.070)	43(.189)	11(.031)	126(.160)	1(.100)		280(.096)
	Foreign	<u>4(.027)</u>	<u>78(.102)</u>	<u>14(.150)</u>	<u>2(.016)</u>	<u>52(.184)</u>	<u>2(.222)</u>		<u>152(.107)</u>
		10	171	57	13	178	3		432
1983-84	Citizen	9(.035)	92(.065)	41(.182)	12(.035)	115(.150)	3(.130)		272(.089)
	Foreign	<u>5(.040)</u>	<u>76(.098)</u>	<u>16(.168)</u>	<u>9(.059)</u>	<u>37(.128)</u>	<u>0</u>		<u>143(.099)</u>
		14	168	57	21	152	3		415
1984-85	Citizen	10(.031)	111(.074)	32(.104)	7(.019)	128(.161)	3(.142)		291(.088)
	Foreign	<u>3(.026)</u>	<u>76(.098)</u>	<u>15(.167)</u>	<u>11(.065)</u>	<u>50(.167)</u>	<u>1(.500)</u>		<u>156(.108)</u>
		13	187	47	18	178	4		447
1985-86	Citizen	7(.026)	119(.080)	46(.157)	4(.010)	122(.156)	3(.115)		301(.092)
	Foreign	<u>3(.017)</u>	<u>89(.101)</u>	<u>12(.102)</u>	<u>5(.030)</u>	<u>46(.144)</u>	<u>1(.166)</u>		<u>156(.094)</u>
		10	208	58	9	168	4		457
1986-87	Citizen	12(.039)	137(.084)	39(.155)	6(.014)	116(.014)	5(.250)	5(.096)	319(.091)
	Foreign	<u>2(.012)</u>	<u>80(.010)</u>	<u>10(.093)</u>	<u>10(.060)</u>	<u>42(.015)</u>	<u>0(0)</u>	<u>0(0)</u>	<u>140(.093)</u>
		14	217	49	16	158	5	5	459
1987-88	Citizen	9(.029)	147(.094)	36(.151)	9(.024)	119(.145)	3(.115)	5(.104)	328(.097)
	Foreign	<u>11(.081)</u>	<u>99(.140)</u>	<u>17(.145)</u>	<u>7(.040)</u>	<u>53(.180)</u>	<u>0(0)</u>	<u>1(.111)</u>	<u>188(.130)</u>
		20	246	53	16	172	3	6	516

Note: Tables IV, V, and VI, which normally appear at this point in the report of the Office of the Dean of the Graduate School(ODGS), were not available at press time for this year's report.

TABLE VII
WOMEN GRADUATE STUDENT ENROLLMENT
Comparison of Fall Term Enrollments - 1986 & 1987

	<u>Number of Women</u>		<u>Percentage Women</u>	
	<u>1986</u>	<u>1987</u>	<u>1986</u>	<u>1987</u>
<u>School of Architecture & Planning</u>				
Architecture	79	68	28%	25%
Urban Studies & Planning	79	77	44%	44%
	158	145	34%	33%
<u>School of Engineering</u>				
Aeronautics & Astronautics	19	16	9%	8%
Chemical Engineering	33	40	14%	17%
Civil Engineering	39	39	14%	15%
Elec. Engineering & Comp. Science	101	102	15%	15%
Materials Science	58	59	22%	26%
Mechanical Engineering	41	42	9%	11%
Nuclear Engineering	18	17	12%	12%
Ocean Engineering	11	9	7%	6%
	320	324	13%	14%
<u>School of Humanities & Social Sciences</u>				
Economics	22	16	17%	12%
Linguistics & Philosophy	30	27	45%	39%
Political Science	55	46	34%	30%
	107	89	30%	25%
<u>Sloan School of Management</u>				
	116	88	20%	16%
<u>School of Science</u>				
Applied Biological Sciences	45	40	45%	47%
Biology	66	73	39%	38%
Chemistry	60	57	27%	24%
Earth, Atmospheric & Planetary Science	54	48	28%	27%
Mathematics	12	19	10%	14%
Physics	30	25	11%	9%
	267	262	24%	24%
<u>Whitaker College</u>				
	15	15	29%	26%
<u>HST</u>				
	4	6	17%	21%
TOTALS	987	929	20%	19%

TABLE VIII
WOMEN GRADUATE STUDENT ENROLLMENT
(1974-87)

<u>Fall Term</u>	<u>New</u>			<u>Continuing</u>			<u>Total</u>		
	<u>Women</u>	<u>Total</u>	<u>% of Women</u>	<u>Women</u>	<u>Total</u>	<u>% of Women</u>	<u>Women</u>	<u>Total</u>	<u>% of Women</u>
1974	140	1,061	13%	265	2,407	11%	405	3,468	12%
1975	175	1,113	16%	312	2,490	13%	487	3,603	14%
1976	185	1,220	15%	361	2,554	14%	546	3,774	14%
1977	192	1,184	16%	367	2,640	14%	559	3,824	15%
1978	218	1,259	17%	388	2,685	14%	606	3,944	15%
1979	193	1,202	16%	491	2,944	17%	684	4,146	16%
1980	254	1,308	19%	525	3,076	17%	779	4,384	18%
1981	243	1,272	19%	585	3,269	18%	828	4,541	18%
1982	267	1,306	20%	589	3,183	19%	856	4,489	19%
1983	258	1,302	20%	656	3,329	20%	914	4,631	20%
1984	265	1,290	21%	716	3,467	21%	981	4,757	21%
1985	255	1,375	19%	726	3,546	20%	981	4,920	20%
1986	238	1,288	18%	749	3,691	20%	987	4,979	20%
1987	221	1,167	19%	708	3,665	19%	929	4,832	19%

TABLE IX

COMPARISON OF FALL ADMISSIONS STATISTICS FOR GRADUATE WOMEN AND GRADUATE MEN

Number of Applicants 1986/Number of Applicants 1987

	<u>Women</u>	<u>Men</u>
School of Architecture	250/262(+5%)*	566/603(+7%)*
School of Engineering	415/416(NC)	3504/2896(-17%)
School of Humanities & Social Science	162/173(+7%)	483/486(NC)
Sloan School of Management	342/349(+2%)	1416/1441(+2%)
School of Science	390/412(+6%)	1324/1292(-2%)
Whitaker College	46/38(-17%)	58/75(+29%)
HST	1/2(+100%)	9/12(+33%)
TOTALS	1606/1652(+3%)	7360/6805(-8%)

* Numbers in parentheses indicate the % change in number of applicants from 1986 to 1987.

TABLE X

COMPARISON OF WOMEN ENROLLED WITH WOMEN DEGREE RECIPIENTS, 1987-88

	<u>% of Women Enrolled</u>		<u>% of Degrees awarded to Women</u>	
			<u>Masters</u>	<u>Doctorates</u>
Architecture and Planning	33% (34%)	(145/444)	31% (44/143) (38%)	55% (11/20) (43%)
Engineering	14% (13%)	(324/2280)	17% (84/507) (16%)	8% (19/240) (11%)
Humanities & Social Science	25% (30%)	(89/355)	38% (5/13) (39%)	23% (12/53) (24%)
Sloan School of Management	16% (20%)	(88/555)	18% (43/241) (24%)	13% (2/16) (25%)
Science	24% (24%)	(262/1112)	31% (10/32) (24%)	25% (38/152) (23%)
Whitaker College	26% (29%)	(15/57)	0% (0/1)	33% (2/6)
HST	21% (17%)	(6/29)	0% (0/0)	0% (0/3) (20%)
<u>TOTAL</u>	19% (20%)	(929/4832)	20% (186/937) (22%)	17% (84/490) (18%)
ALL DEGREES			19% (270/1427) (21%)	

(%) = 1986-87 figures

TABLE XI

Degrees Awarded to Women by School

	<u>1978-79</u>	<u>1979-80</u>	<u>1980-81</u>	<u>1981-82</u>	<u>1982-83</u>	<u>1983-84</u>	<u>1984-85</u>	<u>1985-86</u>	<u>1986-87</u>	<u>1987-88</u>
<u>Architecture & Planning</u>										
Master's*	33	41	48	51	48	50	48	62	64	44
Doctor's	3	5	6	2	6	2	7	4	6	11
<u>Engineering</u>										
Master's	50	51	62	84	72	81	77	95	92	84
Doctor's	4	7	14	10	14	7	15	20	24	19
<u>Humanities & Social Sciences</u>										
Master's	3	3	3	5	5	2	7	5	7	5
Doctor's	4	12	14	10	14	20	14	14	12	12
<u>Sloan (XV, XV-A, XV-P)</u>										
Master's	45	34	49	47	47	54	57	48	69	43
Doctor's	0	1	1	0	3	4	2	0	4	2
<u>Science</u>										
Master's	14	27	21	25	25	23	6	9	10	10
Doctor's	18	20	26	23	29	25	37	47	34	38
<u>Operations Research (XV-B)</u>										
Master's	0	0	1	2	1	1	1	1	2	1
Doctor's	0	0	2	0	1	0	0	0	0	1
<u>WHOI</u>										
Doctor's	0	1(VII) 1(XII)	2(XII)	3(XII) 1(XIX)	2(XII) 1(XIX)	1(VII) 2(XII)	2(XII)	1(VII)	3(XII)	1(I) 3(VII) 6(XII)
<u>HST</u>										
Doctor's	-	-	-	-	1	0	1	1	1	0
<u>Whitaker College</u>										
Doctor's	-	-	-	-	-	-	-	-	1	2
<u>TOTALS</u>										
Master's	145	156	184	214	198	211	196	220	244	187
Doctor's	29	47	65	49	71	61	78	87	85	95

*M. Arch., MCP, SM

TABLE XII
COMPARISON IN NUMBERS OF DEGREES AWARDED TO MEN AND WOMEN
1977-78 to 1987-88

	<u>Master's</u>			<u>Doctor's</u>			<u>Engineer's</u>			<u>All</u>		
	<u>Women</u>	<u>Total</u>	<u>% of Women</u>	<u>Women</u>	<u>Total</u>	<u>% of Women</u>	<u>Women</u>	<u>Total</u>	<u>% of Women</u>	<u>Women</u>	<u>Total</u>	<u>Women</u>
1977-78	135	934	14%	48	425	11%	5	108	5%	183*	1359*	13%**
										188	1467	13%
1978-79	145	968	15%	29	387	7%	2	65	3%	174*	1355*	13%**
										176	1420	12%
1979-80	156	984	16%	47	386	12%	3	77	4%	203*	1370*	15%**
										206	1447	14%
1980-81	184	1018	18%	65	396	16%	3	72	4%	249*	1414*	18%**
										252	1486	17%
1981-82	214	1118	19%	49	403	12%	5	64	8%	263*	1521*	17%**
										268	1585	17%
1982-83	198	1124	18%	71	432	16%	0	67	0%	269*	1556*	17%**
										269	1623	17%
1983-84	211	1084	19%	61	415	15%	9	73	12%	272*	1499*	18%**
										281	1572	18%
1984-85	196	1055	19%	78	446	17%	3	56	5%	274*	1501*	18%**
										277	1557	18%
1985-86	220	1059	21%	87	457	19%	3	54	5%	307*	1516*	20%**
										310	1570	20%
1986-87	244	1150	21%	85	459	19%	4	42	10%	329*	1609*	20%**
										333	1651	20%
1987-88	187	1056	18%	95	516	18%	5	49	10%	282*	1572*	18%**
										287	1621	18%

*Without Engineer's Degrees

TABLE XIII
MINORITY GRADUATE STUDENT ENROLLMENT

Fall 1987

	BA	PR	MA	AI	Total Minority	% change From 1986	Total Regular Grads	% Minority
<u>School of Architecture & Planning</u>								
Architecture	2	2	0	1	5	-38	258	2
Urban Studies & Planning	15	1	7	0	23	+44	144	16
School Totals	17	3	7	1	28	+17%	402	7%
<u>School of Engineering</u>								
Aeronautics & Astronautics	3	1	0	0	4	-50	199	2
Chemical Engineering	3	0	2	1	6	+50	235	3
Civil Engineering	2	1	2	0	5	+67	254	2
Electrical Eng'g. & Comp. Sci.	17	5	6	0	28	0	669	4
Materials Science	1	1	0	0	2	-60	225	1
Mechanical Engineering	7	4	1	0	12	+33	387	3
Nuclear Engineering	0	0	2	0	2	-33	146	1
Ocean Engineering	1	0	0	0	1	+100	158	1
School Totals	34	12	13	1	60	+3%	2273	3%
<u>Sloan School of Management</u>								
Two-Year's Master's Program	7	2	4	0	13	-13	390	3
Sloan Fellows	5	0	0	0	5	+25	56	9
Operations Research	0	0	0	0	0	0	18	0
Ph.D. Program	0	0	0	1	1	0	85	1
School Totals	12	2	4	1	19	-5%	549	3%
<u>Humanities & Soc. Sci. School</u>								
Economics	2	2	1	1	6	+50	119	5
Linguistics & Philosophy	0	1	0	0	1	-50	63	2
Political Science	2	1	1	0	4	-43	120	3
School Totals	4	4	2	1	11	-15%	320	4%
<u>School of Science</u>								
Applied Biological Sciences	3	0	0	0	3	-25	86	3
Biology	2	0	0	0	2	-50	190	1
Chemistry	2	1	2	1	6	+50	239	3
Earth, Atmospheric, & Planetary	0	0	0	0	0	0	175	0
Mathematics	1	0	0	0	1	-50	131	1
Physics	9	2	3	0	14	0	288	5
School Totals	17	3	5	1	26	-7%	1109	2%
<u>Whitaker College</u>								
	0	0	1	0	1	-50%	57	2%
<u>Health Science & Technology</u>								
	1	0	2	0	3	+200%	29	10%
GRAND TOTAL	85	24	34	5	148	+1%	4721	3%

TABLE XIV

TRENDS IN MINORITY GRADUATE ENROLLMENT AT MIT
(Figures do not included non-resident students)

<u>School</u>	<u>1977</u>	<u>1978</u>	<u>1979</u>	<u>1980</u>	<u>1981</u>	<u>1982</u>	<u>1983</u>	<u>1984</u>	<u>1985</u>	<u>1986</u>	<u>1987</u>
Architecture & Planning	44	46	45	57	41	31	35	26	20	24	28
Engineering	40	44	47	58	55	55	62	58	62	58	60
Management	20	13	9	16	10	12	7	18	17	20	19
Humanities and Social Sciences	21	16	9	15	9	12	14	13	18	13	11
Science	32	28	34	25	25	28	27	26	22	28	26
HST	-	-	-	-	-	-	-	-	-	2	3
WHITAKER COLLEGE	-	-	-	-	-	-	-	-	-	1	1
Minority Total	157	147	144	171	140	138	145	141	139	146	148
Regular Graduate Total	3824	3944	4146	4327	4435	4349	4631	4603	4920	4424	4721

BLACK GRADUATE ENROLLMENT

<u>School</u>	<u>1982</u>	<u>1983</u>	<u>1984</u>	<u>1985</u>	<u>1986</u>	<u>1987</u>
Architecture & Planning	23	25	19	12	15	17
Engineering	34	41	41	38	37	34
Management	12	5	14	13	13	12
Humanities & Social Sciences	5	8	5	8	8	4
Science	18	20	20	18	20	17
HPM	-	-	-	-	1	0
HST	-	-	-	-	1	1
Total Black Enrollment	93	99	99	89	95	85

TABLE XV
 MINORITY APPLICANTS RECEIVED, ADMITTED, AND ENROLLED
 1986-87 vs 1987-88

	1986-87			1987-88		
	Rec'd	Ad	Enrolled	Rec'd	Ad	Enrolled
<u>Architecture & Planning</u>						
Architecture	12	2	2	12	4	3
Urban Studies & Planning	7	7	6	21	21	16
Ctr for Real Est Development	-	-	-	4	2	1
	<u>19</u>	<u>9</u>	<u>8</u>	<u>37</u>	<u>27</u>	<u>20</u>
<u>Engineering</u>						
Aeronautics & Astronautics	5	2	1	5	3	0
Chemical Engineering	1	1	1	7	5	1
Civil Engineering	1	1	1	5	3	2
Electrical Engineering	33	8	7	33	12	10
Materials Science	1	1	1	0	0	0
Mechanical Engineering	10	6	3	8	4	3
Nuclear Engineering	0	0	0	0	0	0
Ocean Engineering	0	0	0	2	2	1
	<u>51</u>	<u>19</u>	<u>14</u>	<u>60</u>	<u>29</u>	<u>17</u>
<u>Sloan School of Management</u>	<u>38</u>	<u>16</u>	<u>11</u>	<u>34</u>	<u>22</u>	<u>10</u>
<u>Humanities & Social Sciences</u>						
Economics	3	0	0	5	3	3
Linguistics & Philosophy	0	0	0	0	0	0
Political Science	3	3	1	4	0	0
	<u>6</u>	<u>3</u>	<u>1</u>	<u>9</u>	<u>3</u>	<u>3</u>
<u>School of Science</u>						
Applied Biological Sciences	3	0	0	8	2	2
Biology	5	0	0	4	2	0
Chemistry	6	4	3	6	3	3
Earth, Atmospheric & Planetary	2	0	0	0	0	0
Mathematics	2	2	2	0	0	0
Physics	7	5	4	11	7	1
	<u>25</u>	<u>11</u>	<u>9</u>	<u>29</u>	<u>14</u>	<u>6</u>
<u>Whitaker College</u>	7	1	1	0	0	0
<u>Health Sciences & Technology</u>	0	0	0	1	1	1
 GRAND TOTAL	 146	 59	 44	 170	 96	 57

TABLE XVI

MINORITY GRADUATE DEGREE RECIPIENTS, 1987-88

(September, February, June Degree Lists)

	Black American	Mexican American	Puerto Rican	American Indian	Total
Master's Degree	13	6	10	1	30
Engineer's Degree	0	0	0	0	0
Doctor's Degree	<u>6</u>	<u>0</u>	<u>1</u>	<u>0</u>	<u>7</u>
Total	19	6	11	1	37

Graduation Date	Master's Degree				Engineer's Degree				Doctor's Degree			
	BA	MA	PR	AI	BA	MA	PR	AI	BA	MA	PR	AI
September	0	0	2	1	0	0	0	0	2	0	1	0
February	1	1	1	0	0	0	0	0	0	0	0	0
June	<u>12</u>	<u>5</u>	<u>7</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>4</u>	<u>0</u>	<u>0</u>	<u>0</u>
Total	13	6	10	1	0	0	0	0	6	0	1	0

School	Master's	Engineer's	Doctor's	Total
Architecture & Planning	7	0	0	7
Engineering	10	0	3	13
Humanities & Social Sciences	0	0	1	1
Science	2	0	3	5
Sloan School of Management	<u>11</u>	<u>0</u>	<u>0</u>	<u>11</u>
Total	30	0	7	37

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 1987-88, LIS offered 37 different courses. The fields of instruction included analog and digital electronics including microprocessors through advanced applications, computer literacy, computer programming in BASIC and C, mechanical drafting, geometric dimensioning and tolerancing, mechanical computer aided drafting, printed circuit board design, blueprint reading, machine tools, alarm technology, building maintenance, gate arrays and cell based design, scientific glassblowing, and housebuilding. In addition, refresher courses were offered in mathematics to support both the drafting and electronics curricula. New courses were introduced in electronic imaging and machine vision, intermediate calculus, and advanced C programming. In addition, for the first time, a mechanical engineering review course was offered for registered professional engineer examination candidates.

A two-day intensive course in electronic imaging and machine vision was offered on campus for engineers in local companies.

LIS admitted a total of 884 students to its courses in 1987-88. Of those enrolled, 73 percent successfully completed the certificate requirements. Among those who completed courses were 65 MIT employees and one regular MIT student. Twelve students earned the Certificate in Electronics Technology, and six 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 1986 - 1,528 registrations in 62 special programs

Summer 1987 - 1,800 registrations in 66 special programs

Foreign citizens comprise approximately 12 percent of this registration.

Regular Subjects

Graduate students comprise 83 percent of the student body in summer. The 1987 registration of 3,155 students was a decrease from 3,178 in 1986.

FREDERICK J. McGARRY

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-first 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-one 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, and 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 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, Tuesday and Thursday from 3:00 to 5:30 p.m. and Wednesday from 3:00 to 7:30 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.

College Report, Class of 1988. Graduating seniors have enrolled in the following institutions: Boston University, Bunker Hill Community College, Fitchburg State College, Hampton University, Howard University, North Shore Community College, and the University of Massachusetts at Amherst.

RONALD S. CRICHLOW

MIT/WHOI Joint Program in Oceanography and Oceanographic Engineering

The MIT Joint Program with the Woods Hole Oceanographic Institution (WHOI) realized one of its major long-term goals this spring when the MIT Corporation approved a joint Master's degree between MIT and WHOI. The WHOI trustees had approved a joint SM in 1986.

The first joint SM degree was awarded at the May 1988 commencement. Overall, the Joint Program graduated 30 students in 1987-88; of these, 26 received the doctorate, three received the Engineer's degree, and one received the Master's. The breakdown by discipline is as follows: Chemical Oceanography (4); Biological Oceanography (3); Marine Geology and Geophysics (8); Physical Oceanography (7); and Oceanographic Engineering (8).

Due to the large number of students who graduated this past year, enrollment in the Joint Program dropped to 101 as of June 1988. The projected enrollment estimate for September 1988 is 118 students, with 20 each in Biological Oceanography, Chemical Oceanography, and Marine Geology and Geophysics; 30 in Physical Oceanography; and 28 in Oceanographic Engineering.

There were 140 applicants to the Joint Program for 1988-89, a figure slightly lower than that of last year. Thirty-six students were admitted to the program; of these, 28 (78 percent) accepted our offer of admission. The Joint Program is pleased to note that one-third of the entering class are women. Of the incoming students, all but seven will be doctoral candidates. In addition, four of the entering students have NSF fellowships, one has an NSERC from Canada, and one was awarded NSF, ONR, and Hertz Foundation fellowships!

In the spring of 1988 the first joint research effort with the Bermuda Biological Station (BBS) was successfully carried out by a student in Chemical Oceanography. This joint research was made possible by a grant from Research Industries, Inc. The Joint Program hopes to encourage more research ventures with the BBS in the future.

After five years as MIT Director of the Joint Program, Professor Arthur Baggeroer will step down in order to concentrate on his Arctic acoustics research. Under Professor Baggeroer's leadership, a video-voice microwave link was set up between MIT and WHOI; the joint SM degree was established; the joint research venture with the BBS was funded; and efforts were carried out to increase the number of students who apply to graduate schools in oceanography. Professor Baggeroer's term will end August 31, 1988; a new director has not yet been named.

MARY ATHANIS

Office of the Dean for Student Affairs

INTRODUCTION

Of Critical Importance

We were stunned by the tragic suicides that occurred this year. Together and individually, we are making every effort to be as sensitive and as responsive to students as possible in the hope that additional tragedies can be avoided. Many groups have met throughout the year to discuss questions of pace, pressure, and the academic environment as they relate to suicide. These have included a subcommittee of the Committee on Student Affairs, medical staff, students, staff from various support services, and other members of the MIT community. We will continue to be very strongly and actively involved in discussions and outreach activities during the coming year, and we welcome contributions to our discussions from members of the MIT community and any other interested individuals.

Major Developments

Several important surveys were conducted in our area this year to determine whether existing programs needed to be strengthened or whether additional programs and services should be developed on behalf of students. A survey, conducted by the International Issues Group (an ad hoc group of faculty and staff), will be used to address the needs of international students in areas such as: residence and orientation; familiarity with support services; and academic, social, and personal matters. A companion study of graduate and undergraduate American students was also made. The results of this survey will be combined with those of an earlier survey of departments, research centers, and laboratories conducted last summer to learn about issues facing international students and scholars from the perspective of individuals in close daily contact with members of this group of students and visitors.

A second survey to determine the level of interest and activity on the part of students, faculty, and staff in public service has just been completed. We expect to produce a report on our findings by this fall, with recommendations for coordinating and strengthening participation in community service across the Institute. This survey was motivated by a desire to provide greater opportunities for our students to use their talents and interests to the benefit of others.

A third survey, conducted by the Minority Student Issues Group (MSIG), was sent to department chairs and selected office heads to help determine the extent to which the Institute's environment has become more supportive of minority students since the release in October, 1986 of the report on the racial climate on the MIT campus. The results of this survey will be included in the MSIG's second report to be released in the fall of 1988. This second report will focus primarily on MIT's recruitment, admissions, and financial aid procedures as they relate to minority students, as well as on the Institute's student support services and the extent to which they promote success among minority students.

This year the student version of the Minority Student Issues Group (S-MSIG) focused on the issue of the recruitment of minority faculty and students to the Institute. Our meetings produced a set of recommendations and a proposal for specific actions to intensify recruitment efforts. A letter to the Equal Opportunity Committee (EOC) detailed a variety of approaches that EOC might suggest in its meetings with departments regarding minority recruitment. The proposal which was sent to the President, Provost, and Academic Deans outlined an approach to the recruitment of minority graduate students using as a model a highly successful recruitment program in place in the Department of Urban Studies and Planning. The recommendation was that other Schools adopt a similar approach.

Major developments in other areas include significant changes in the Freshman Advising Program, the Housemaster-Graduate Resident Program, and the initiation of a review of the Independent Living Group System. We are re-defining and broadening the role of freshman advisors, with emphasis on intensive and frequent contact, and more awareness and sensitivity to the wider spectrum of an individual advisee's needs. Of special note is the highly successful experimental Freshman Advisor Seminar Program, which is described in more detail later in this report. Another important change is concentrating advising with those individuals who do it willingly and effectively. These changes, and others, should greatly improve the overall quality of our freshman advising system.

We have made considerable progress in implementing the recommendations in the report on the Housemaster-Graduate Resident Program. Several faculty now have formal associations with various Institute Houses and Independent Living Groups through the Faculty Fellows Program recommended in the

report. We are also pleased to report the selection of a number of minority students as graduate residents and the appointment of a minority family, Dr. and Mrs. John Wilson, as Associate Housemasters in the system for the next academic year. This development helps to address a major concern regarding the low participation of minorities in the administration of the residential system.

A committee chaired by Professor Robert Kennedy has been appointed to study the Independent Living Group System in light of changing demographics and continued complaints from neighbors of some of the fraternities located in the Back Bay. Of primary concern to the Office of the Dean for Student Affairs (ODSA) is the development of a long-term strategy for insuring the health and viability of the Institute's Independent Living Group System. Such a strategy should take into account the need for change in light of the increasing percentage of women on campus and for greater efforts to attract minority students into the system. The committee expects to complete its report by early Spring 1989.

We were extremely pleased when Professor Travis Merritt agreed to serve as Associate Dean for Student Affairs and Head of the Undergraduate Academic Support (UAS) section. His perspective as a faculty member has had considerable positive influence throughout the ODSA, and we look forward to benefitting further from his experience in the future.

In January, Joyce Gibson, Director of the Office of Minority Education (OME), informed us that she would be leaving the Institute at the end of the academic year to pursue other professional interests. Joyce has been a major asset to the Office and to the Institute. She and her staff have increased considerably the familiarity with and support of OME's goals and programs among faculty and staff around the Institute. In addition, they have made OME's activities more inclusive and supportive of students from the various underrepresented minority groups on campus. We wish Joyce well in her new position with the Efficacy Institute, a consulting group that works with public school systems, colleges, and universities in support of minority students.

Other changes, including promotions and the hiring of new staff, are described in the reports of the various sections which follow this introduction. I want to acknowledge here the addition of Betty Sultan as Staff Assistant to the Dean and of Alberta Lipson as our first Assistant Dean for Research. They have added considerable strength to our staff. Mary Jasinski left the Central Office to become Assistant to the Registrar.

Affirmative Action Successes and Objectives

The ODSA continued to maintain a strong commitment to Affirmative Action during the year, with a staff that was 28% minority and 32% male. The following table reflects the race/ethnicity and gender profile, as of March 3, of the 47 full- and part-time positions in the ODSA.

ODSA AFFIRMATIVE ACTION PROFILE, FISCAL YEAR 1988

	Minorities	Non-minorities	Total
<u>Admin. & Other Academic Staff</u>			
Male	5	9	14
Female	6	14	20
Subtotal	11	23	34
<u>Support Staff</u>			
Male	0	1	1
Female	2	10	12
Subtotal	2	11	13
<u>TOTAL</u>	<u>13</u>	<u>34</u>	<u>47</u>

The five minority men in the administrative and other academic staff category include 3 Blacks, 1 Mexican American, and 1 Asian. The six minority women in this category include 5 Blacks and 1 Asian American. Not included in these numbers are the Dean-On-Call who is a Black male and a Native American female who serves as a consultant to the Office of Minority Education (OME) on special projects. The 2 minority females among the 13 support staff members are Black.

During Fiscal Year 1988, minorities and males together represented 53% (33% minorities and 20% males) of the new full- and part-time persons hired. We have accomplished our goal of having minority presence in each of the Office's sections. The hiring of at least 1 Asian American to the full-time Administrative Staff remains as a goal for Fiscal Year 1989.

The ODSA staff is a model of what can be accomplished in affirmative action when highly-talented women and men of diverse racial and ethnic backgrounds work together in an atmosphere of mutual respect and admiration. I am proud of this staff and I am confident that together we will continue to not only make the MIT environment more supportive of all students but that we can continue to have a positive influence on other areas of the Institute.

SHIRLEY M. McBAY

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 1987-88, in addition to maintaining its established administrative functions, UAS took special steps to: 1) re-define and radically strengthen 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; and 4) improve the organization, schedule, and academic emphasis of the Residence/Orientation period.

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

Freshman Advising Program

The primary counseling of freshmen during 1987-88 was carried out by 234 advisors (118 faculty, 9 instructors/lecturers, 15 research staff members, 27 graduate students, and 65 members of the administrative staff). Supporting these advisors were 350 undergraduates who served as associate advisors.

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; 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 making an effort to keep advisors better informed and supported through various orientation programs, streamlining of paperflow, revision of the Advisor's Guide, refinement of the early warning system which alerts advisors to advisees experiencing academic difficulty, and modest support for special events involving advisees and advisors.

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

<u>Academic Year</u>	<u>Required Withdrawals</u>	<u>CAP Warnings</u>	<u>UAS Letters</u>	<u>Total Academic Actions</u>
1987-88	10	91	91	192
1986-87	8	91	84	183
1985-86	10	94	73	177
1984-85	13	79	53	145
1983-84	12	96	89	197

Undesignated Sophomore Advising Program

Twenty-six faculty and staff advisors counseled the 93 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 20. The respective fall and spring student figures for 1986-87 were 64 and 13.

Residence/Orientation (R/O)

Each fall's Residence/Orientation Program for new undergraduates is produced by students in collaboration with UAS and other ODSA staff. This year's R/O was coordinated by Steven Margossian and Michael Franklin, both '88. A number of changes were made in both the residence selection and orientation programs.

For the first time freshmen were introduced to the residence selection process through a skit written and performed by student members of Dramashop and the R/O Committee. The dormitory selection process was also streamlined so that two days of lotteries were held instead of three.

Academic orientation was strengthened by two new programs. Freshmen were encouraged to experience different academic and research environments through Academic Explorations, which offered them opportunities to join 20 tours, demonstrations, and lectures. The response to this program was so overwhelming that plans have been made to double the number of events for next year. The other innovation in academic orientation was a series of events centered around a common text read by new students. During the summer all incoming students received a copy of The Machine in the Garden by Professor Leo Marx. Once on campus, they had an opportunity to see the movie, The Mosquito Coast. In the "Great Cane Debate" in Kresge Auditorium, a panel of faculty moderated by President Paul Gray discussed the issues raised by the book, and then students had a chance to discuss the book and movie with faculty and staff in their living groups. Professor Kenneth Manning was instrumental in organizing these events.

Because Parents Weekend fell on Labor Day weekend, more parents attended. To accommodate the increase, the luncheon for parents was expanded to an outside picnic for which more than 600 parents and students bought tickets.

Administrative Support to the Committee on Academic Performance (CAP)

The CAP was chaired this year by Professor Fred Schweppe. During the year, the Committee handled approximately 400 petitions from individual students requesting readmission and exceptions to certain regulations of the faculty. A total of 53 Required Withdrawals (representing less than 1 percent of the undergraduates) and 304 Warnings (approximately 4 percent) were voted for the academic year, distributed by class as follows.

	<u>Required Withdrawals</u>	<u>CAP Warnings</u>
Class of 1988	19	48
Class of 1989	9	66
Class of 1990	15	99
Class of 1991	10	91

The Undergraduate Seminar Program

The types of seminars offered under the Undergraduate Seminar Program continued to diversify this year. Fifty-nine listings for Fall term included 27 Freshman Advisor Seminars and 6 "hybrids" admitting both advisees and other students. In the Spring there were 47 seminars in all, of which 7 were House Seminars hosted by residence halls and independent living groups. The total of 106 represented a significant increase over last year's 92, although total undergraduate registration (1156) fell off somewhat, largely because of the low enrollment ceilings imposed on most Advisor Seminars. The overall total of enrolled freshmen was 642.

Planning for next year's seminar array aims to: 1) increase the number of seminars offered during IAP; and 2) encourage the development of seminars which expressly reinforce the ODSA's new public service initiative. We also intend to persevere in our pointed effort, supported by the Institute's Committee on Curricula, to insist on more vigorous standards (involving such matters as reasonably small seminar size, assigned work, and reliable means of accountability) in approving new seminars and urging the revision of established ones.

Freshman Initiatives

At the close of its second year, the Initiatives program, designed to quicken and intensify intellectual/social interaction between entering students and MIT faculty, is displaying certain clearly promising trends on which expansion and further experiment may confidently be based. Key to these successes have been two factors enhanced considerably since the program's first year: 1) generally strong support from the leadership and teaching staff of the academic departments and from several Institute committees concerned with educational reform; and 2) a widespread spirit of practical cooperation and involvement on the part of student living groups.

Freshman Advisor Seminars - Spearheading the effort to improve radically the quality of freshman advising, these Fall term seminars, which intermingle counseling and intellectual mentorship, continue to win the favor of advisors and advisees alike. This year 33 of these offerings were able to accommodate 252 of the 659 freshmen who applied for them. Energetic recruitment, aided by the program's good reputation, has produced 65 Advisor Seminars for Fall 1988, representing 24 of MIT's 28 academic departments and sections.

Residence-Based Advising - The advisory "clusters" in Baker House and 500 Memorial Drive did well this year. In Baker, 10 advisors and 29 associate advisors served 36 advisees; in 500, the numbers in each category were 6, 16, and 28 respectively. Proximity of associate advisors and freshmen contributes heavily to the success of Residence-Based Advising. Although the envisioned group activities involving the entire cluster have been infrequent and spottily attended, surveys suggest that this system is more favorably received by freshmen than the conventional advising system.

Team Advising - The proximity here is among advisors--teams of two to four from the same department, lab, or office--who advise collaboratively, fill in for each other when necessary, and provide their advisees with a wider view of their collective professional area. As in Residence-Based Advising, full group activities have proven difficult to arrange. In 1987-88, this system attracted far fewer faculty members than the year before. There were 12 teams involving 31 advisors (only 3 of them faculty), 42 associate advisors, and 102 advisees.

House Seminars - Recruitment of faculty for this subset of Undergraduate Seminars, hosted by various living groups in the Spring term, has proven very difficult. The after-dinner meeting hour seems to be the main deterrent. Nonetheless, most of the seven House Seminars offered this Spring--with enrollment varying from 9 to 20--were highly acclaimed. For the first time, fraternities (4) became involved in the program. Although priority is given to freshmen, the freshman enrollment level was somewhat disappointing (18 out of a total of 105 registered undergraduates). In any case, expansion of this program is plainly worth persistent effort, possibly in affiliation with the ODSA's new Faculty Fellows program.

New Initiatives - During the Spring term, UAS was joined by the other ODSA sections in developing support for three significant new ventures for 1988-89, each of them generated in large part out of student initiative and concern, each holding promise of improved community well-being for students generally and freshmen in particular: 1) a system of undergraduate Resident Advisors (RA's) in East Campus, to provide companionship and personal support to the dorm's freshmen in a ratio of 4 or 5 to 1. The RA's, drawn from the junior class, will maintain linkage with UAS, RCA, SAS, and OME, and will work in close association with the Graduate Residents. They will function independently of the Faculty Advisor/Associate Advisor system, as their main concerns are non-academic; 2) a big sister/little sister program in McCormick Hall, with aims similar to those of the East Campus enterprise. Big sisters will be upperclasswomen from the sophomore, junior, and senior years. The target ratio of big sisters to their little sister freshmen is one to one; and 3) an experimental peripatetic House Seminar, the "Lecture Series on the Arts," hosted serially by ten living groups in the Fall term, open to the MIT student community as a whole, with a credit-bearing option (involving written work) available to 24 students.

Independent Activities Period (IAP)

In 1987-88 various deliberative and policy-making groups around the Institute became involved in the first stages of a thorough re-assessment of IAP as a part of the academic calendar and as an element in the educational experience of undergraduates. In its second year under the chairmanship of Professor David Gordon Wilson, the IAP Policy Committee issued a detailed report on the current status and future prospects of IAP, with several recommendations for strengthening its organization and content. The UAS, with approval from the Committee on the Undergraduate Program, is working to implement three of these: 1) a modest increase in the number of sustained, credit-bearing activities available to students who want them; 2) a September "IAP Preview" publication offering early notice of major January activities; and 3) a process by which freshmen work out in written form during the Fall term a tentative plan of their IAP activities, with a follow-up reassessment of their experience at the end of January.

The total number of scheduled activities for IAP '88 was 589 (down from 670 the previous year). Sixty percent of these were single-meeting activities. Twenty-seven percent of the faculty participated.

Wellesley-MIT Exchange

For the nineteenth year the Wellesley-MIT Exchange Program offered MIT and Wellesley students the opportunity to experience a different educational institution and to expand their academic programs through cross-registration.

The number of MIT students cross-registering for Wellesley subjects decreased from 1986-87 levels, as did the number of Wellesley students taking MIT subjects. During the year, 370 MIT students registered for 348 Wellesley subjects, as compared with the 467 MIT students who took 494 Wellesley subjects the previous year. The number of Wellesley students cross-registering at MIT during the year was 278 in 411 subjects. Comparable numbers for the previous year were 359 students in 414 subjects.

The most noteworthy and disturbing trend has been the decline in numbers of MIT students taking Wellesley subjects at Wellesley, a total of only 91 for the year (most of the MIT enrollment in Wellesley offerings were in subjects taught by Wellesley faculty on the MIT campus).

Four MIT students (one each in biology, social studies, mathematics, and chemistry) earned certification as secondary school teachers through the Education Department at Wellesley. The Exchange Program continued to administer a small residence exchange program involving approximately five students from each school.

This was Professor Robert Jaffe's first year as MIT co-chair of the Wellesley-MIT Joint Committee. He has taken the lead in prompting necessary reassessments of the program's usefulness to both schools.

Academic Support and Information Center

Activities in this area continued substantially as described in last year's report. An important new undertaking, still in the planning stage, is an experimental program in residence-based student peer-tutoring, to complement other tutoring opportunities available at the Institute.

Career and Course Orientation

This effort, too, was vigorously carried forward. The second annual Freshman/Faculty Banquet, designed to illuminate students' selection of majors, was a conspicuous success.

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. Especially gratifying was a heightened level of productive contact with the Undergraduate Association (UA).

Staff

The year brought the departure of several valued colleagues and the arrival of promising new staff people. Bonnie Walters moved from her former post as Coordinator of the MIT Writing Requirement to Assistant Dean in charge of freshman advising. Virginia Sorenson assumed the responsibilities of Assistant to the Dean for Freshman Initiatives. Maryglenn Vincens resigned her position as Senior Staff Associate for publications in order to pursue an MBA at Simmons; the difficult task of replacing her is now in progress. Stephen Patterson and Susanna Hinds were promoted to the rank of Staff Associate.

TRAVIS MERRITT	STEPHEN PATTERSON
MARY ENTERLINE	VIRGINIA SORENSON
SUSANNA HINDS	MARYGLENN VINCENS
JEFFREY MELDMAN	BONNIE WALTERS

STUDENT ASSISTANCE SERVICES

For an office that defines itself as a counseling resource, suicide is extremely traumatic for it calls into question our very reason for being. Counseling sessions take on new intensity as counselors seek to read even more closely between the lines. The Academic Year 1987-88 will be remembered because there were more student deaths than during any year in recent memory. Three deaths

were ruled suicide by the Coroner's Office and one death was listed as accidental. In the period following the fourth death, four students were hospitalized because of the seriousness of the threat they posed to themselves. These successful interventions do not counter the tragedies of the year, but they remind us of the efficacy of our work.

Throughout the year members of Student Assistance Services were involved in outreach efforts that responded to community needs and stretched the resources of the office. Deans visited dormitories and talked with faculty groups about the issue of suicide. Other groups that gathered during the year, e.g., Nightline, used the opportunity to discuss questions of pace, pressure, and the general environment as they relate to suicide. A great deal of time has been spent in conversations with parents, students, and community representatives on the topic. The ferment has resulted in new initiatives for the fall aimed at making our helping resources more effective and accessible. These initiatives include the creation of a helping network that will be organized, trained, and publicized, emphasizing person-to-person contacts and the creation of a publication describing various resources.

In addition, we have worked with the Medical Department to develop undergraduate counseling/support groups co-led by psychiatrists. Each psychiatrist will also be involved in the life of a specific dormitory. This increased medical presence will complement our increased outreach and it serves to remind us of the close working relationship we enjoy with the Medical Department.

Individual counseling sessions numbered over 2,300 for the year, not including the visits of international students who came often for support in order to maintain legal status and pursue practical training. There is no way to measure drop-in traffic or the numbers of students touched in group sessions. However, it is clear that the office continues to positively affect the lives of a growing number of students.

Tragedy takes center stage, deflecting awareness from other on-going work. The work done by Milena Levak and Karen Zuffante has served the international community well, and new requirements by the Immigration and Naturalization Service have increased the amount and type of work required by the office. Rules, for example, governing practical training have given students more opportunities and have doubled our work. The International Issues Group continues to examine services offered the international community. Recommendations will be forthcoming, but in the meantime the office is examining closely what reallocation of resources we might make in order to improve both delivery of services and the work load of the office.

As the number of women students increases the needs of the community shift. Lynn Roberson and Jackie Simonis have put together a program that has grown steadily in acceptance and effectiveness. The development of "Net Weight," a support network for women with eating disorders, has gone well and has effectively responded to this growing problem. Programs dealing with the phenomenon of date rape have drawn wide support and have laid the foundation for a redefinition and increased awareness of this growing concern.

The Women Students' Cooperative Board has been a real success. This Board involves both undergraduate and graduate women and helps give direct feedback on the needs of women in our community. It is a crucial and successful component of a program serving an ever increasing and influential segment of the community. Monthly meetings of graduate women students have been successful as have discussion groups in departments. In the future this growing sense of empowerment will influence the Institute in a variety of ways and the statistics indicating the superior academic performance of women suggests that the influence is all for the good.

The admitted class for the coming year will include the largest number of minority students in the history of the Institute. The support services for minority students have significantly improved over the course of the last two years. Marilyn Braithwaite and Arnold Henderson have forged new connections with OME and have given shape and purpose to the discussion groups that had languished in recent years. Marilyn assumed the leadership role in arranging the Martin Luther King Day Celebration and she helped to bring students from Cambridge Rindge and Latin to campus to participate in the program. At a time when community relations are especially sensitive, efforts of this sort are much appreciated and suggest ways for effectively influencing young people.

The more diverse the MIT community becomes, the more pressure we will feel to effectively respond to varied needs while keeping alive an atmosphere where students achieve their educational goals. Efforts such as the Minority Student Issues Group study, the International Issues Group, the Hispanic Student Task Force, and the Asian Student Issues Group all contribute to our ability to effectively read the environment at MIT and make adjustments that enhance the educational experience of all students.

Arnold Henderson spent a disproportionate amount of his time this year on matters related to the Committee on Discipline. As the year unfolded the nature of the cases before the Committee made it clear that our ability to offer effective counsel to students was often compromised. A hard look at the way the whole system works is underway, including a special review for the ODSA by Jeff Meldman, and we hope that a change in our relationship to the Committee will result.

The growing number of students with disabilities indicates that the diversity of the Institute is going beyond ethnic dimensions. A revised guide for disabled students is now available. An ad hoc Committee for Disabled Students has been established and has begun to address Institute-wide issues affecting students with disabilities.

Student Assistance Services has lost a number of important support staff members this past year, including Lillian Sakey who took with her the collected wisdom of thirteen years at the Institute. Each left for her own reasons and we accept a certain degree of flux. The instability their losses generated has influenced the office but current staff members have worked hard to create a team that has responded to the needs of the moment. The result has been far better than we had any right to expect and the sense of unity created in SAS should serve us well in the future. We were especially pleased with the well-deserved promotions of Jackie Simonis to Associate Dean, of Karen Zuffante to Staff Associate, and of Anne St. Onge to Assistant to the Dean.

ROBERT RANDOLPH	LYNN ROBERSON
MARILYN BRAITHWAITE	JACKIE SIMONIS
ARNOLD HENDERSON	ANNE ST. ONGE
MILENA LEVAK	KAREN ZUFFANTE

RESIDENCE AND CAMPUS ACTIVITIES

Undergraduate Housing

Undergraduate crowding in the living groups increased over last year from 124 to 152 rooms, despite the continued steady state in the size of the freshman class. Much of the crowding, we believe, can be attributed to the changing demographics of the entering class and its negative impact on fraternity rush. We expect increased pressure on Institute housing in the coming years as more women students are admitted to the Institute.

Demand for single sex housing for women was once again greater than what was available. We have increased the number of women's spaces in MacGregor and in East Campus; however, additional space will need to be found in the coming years.

Fraternities/Sororities and Independent Living Groups

This year's Rush was not as successful as hoped due to a drop in the percentage of MIT freshman males entering fraternities from 55% in 1986 to 48% in 1987. Entering classes continue to include an increasing number of individuals (women, minority, and international students) who traditionally have not joined the fraternity/independent living group system. As a result, dormitory crowding increased this year and many fraternities experienced membership shortfalls. Since these trends will continue, there is an urgent need for the system to adapt in ways that will maintain its long-term viability.

One of the most pressing issues this year was providing casualty and liability insurance for the houses. National concerns regarding safety and liability issues have resulted in more careful scrutiny by insurance underwriters. As a result, the MIT system underwent its first thorough review in several years as new insurance coverage was sought. One positive outcome has been increased student awareness of potential risk, which led to the adoption last term of an IFC policy designed to more adequately control events where alcohol is served.

Advisor to the Fraternities, Sororities, and Independent Living Groups

This position was divided this year between two individuals (Virginia Sorenson and Steven Margossian), each working part-time. This arrangement was due in part to the decision to delay the recruitment of a replacement for Mark Ertel while the committee established to review the Independent Living Group system began its meetings to sort out long-term issues for the system. A successful search to fill the position for the next academic year has been completed as Neal Dorow will be joining the staff in August.

Faculty Fellows

This year was the first of a three-year experimental Faculty Fellows Program to promote greater interaction between residential students and members of the faculty. Under the leadership of Professor James Mar, 22 faculty members were appointed as Fellows for six dormitories and two fraternities. The second year is expected to provide sustained regular interaction, as well as an opportunity to expand to additional independent living groups.

Discipline and Harassment Cases

A number of student discipline and harassment cases were adjudicated by the Residence and Campus Activities (RCA) staff this year. In summary, one student and two alumni were declared persona non grata, seven were suspended from Institute houses, 26 were placed on Dean's Office Probation, 32 were given written warnings, eight were required to write letters of apology, and nine were required to perform acts of public service. Included in these figures were five formal disciplinary hearings involving nine students. Several other cases were dealt with through verbal warnings. In addition, action against living groups resulted in probation for one house and suspension of rush privileges for one year for another. Charges included possession of an infernal device, destruction of property, assault and battery, alcohol abuse, filing a false police report, and disorderly behavior.

Campus Activities

The Campus Activities Office experienced a particularly hectic year due to the renovation of the Student Center which began in August 1987. The construction placed an added burden on the scheduler and managers of the facility, challenging them to find alternative sites on campus to run events without sacrificing quantity and quality.

The biggest success of the year was, in fact, accomplished by students. Mark Kantrowitz '89 and several other students issued the first comprehensive report on the condition and use of student activity space on the MIT campus. Needless to say, we have too little space for too many activities. On-going improvements to the quality of space as well as discussions on how to enhance its use will be a focus of next year's discussions.

The Undergraduate Association held a referendum this March on whether or not a student activity fee should be levied. This too was the first attempt of its kind in recent memory (10 years) and though it was defeated, it has heightened the awareness of the community to the need for additional funds to support activities.

The Activities Office continued to offer both leadership development and alcohol education programs to interested students. The T.I.P.S. (Training for Intervention Procedures by Servers of Alcohol) program is winning acceptance by students as we trained about 60 people during the academic year. Plans are in the works to train about 200 students in the fall. Students are reluctant to accept any restrictions on alcohol consumption and this continues to be a challenge for our office.

Graduate Student Housing

In November 1987 the Graduate Student Housing Client Team was formed to review the feasibility of affordable housing for MIT graduate students.

A new graduate dormitory has been scheduled for completion in November 1989. The dormitory will be located in the building at 143 Albany Street and will house approximately 185 students. The estimated cost of renovations is \$14 million plus project cost. The Institute is presently seeking a special housing permit and construction contractor for the building.

The need for graduate housing has greatly increased since the construction of Tang Hall and the renovations of Ashdown House. The Client Team hopes that 143 Albany Street will be the first in a series of affordable housing for graduate students.

Talbot House

Talbot House has become increasingly popular in its function as an MIT retreat house, and this was the busiest year in its history. The house was in use 182 days, with 64 different groups making visits to the house. A record 1578 individuals were able to visit the house, of whom 1142 were students, and 436 were staff, faculty, or alumni. The house was unoccupied for only two days during January and February, and six more groups were able to visit the house over last year as a result of limiting stays to a maximum of two days.

Housemaster and Graduate Resident Programs

Much to our regret, Housemasters Jay and Margaret Keyser of Senior House, and Housemasters Frank and Victoria Solomon of Bexley Hall, decided to leave the residential system at the end of this academic year. We are very grateful to these two families for their significant contributions to their respective Houses and to the overall residential system. Professor William Orme-Johnson and his wife Carol will become Housemasters at Bexley Hall, and we expect to finalize replacements for the Keyseres during July.

Monthly Housemaster meetings were held during the academic year with such agenda items as the Institute's alcohol policy, discipline procedures, AIDS and related health issues, fraternities, and R/O.

Staff Changes

We are very pleased that Barbara Fienman was promoted to Assistant Dean for Student Affairs and that Jack Keefe was appointed to the position of Staff Associate for Resident Programs, replacing Ann Braden who left the section to take a position in the Bursar's Office.

JAMES R. TEWHEY
ANDREW M. EISENMANN
BARBARA M. FIENMAN

STEPHANIE HARRISTON-DIGGS
JOHN E. KEEFE
RETA M. LEE

FALL 1987 INSTITUTE GRADUATE HOUSE COUNT

	<u>MEN</u>	<u>WOMEN</u>	<u>TOTAL</u>
<u>SINGLE</u>			
Ashdown	318 (81%)	73 (19%)	391 (100%)
Green	0 (0%)	46 (100%)	46 (100%)
Tang	342 (85%)	62 (15%)	404 (100%)
Graduate Residents	19 (48%)	21 (53%)	40 (100%)
	<u>679 (77%)</u>	<u>202 (23%)</u>	<u>881 (100%)</u>
<u>MARRIED</u>			
Eastgate*	171 (87%)	26 (13%)	197 (100%)
Westgate*	189 (90%)	20 (10%)	209 (100%)
Graduate Residents*	23 (88%)	3 (12%)	26 (100%)
	<u>383 (89%)</u>	<u>49 (11%)</u>	<u>432 (100%)</u>

*There are 17 couples in Eastgate, 15 in Westgate, and 5 Graduate Resident couples where both members are students.

Note: Total normal capacity of all MIT graduate residences is 1247. This number does not include graduate residents, and includes only one member of two student couples.

October, 1987

FALL 1987 INSTITUTE UNDERGRADUATE HOUSE COUNT

HOUSE	1		2		3		4		Other		Total		TOTAL	CAP	VACANCIES	CROWDS
	M	F	M	F	M	F	M	F	M	F	M	F				
Baker	34	42	37	47	58	36	63	31	1	0	193	156	349	337	1	13
Bexley	18	8	10	16	24	5	22	16	1	0	75	45	120	120	0	0
Burton	49	50	50	53	61	24	55	29	0	0	215	156	371	344	0	27
East Campus	65	28	41	44	70	28	69	40	1	0	246	140	386	362	0	24
MacGregor	46	29	77	4	101	4	65	0	2	0	291	37	328	328	0	0
McConnick		54		64		52		66		0		236	236	219	0	17
New House	37	33	32	24	34	16	32	15	0	0	135	88	223	206	0	17
French House	2	5	2	4	5	1	3	3	0	0	12	13	25	24	0	1
German House	4	0	5	2	3	1	6	0	0	0	18	3	21	21	0	0
Russian House	1	3	2	4	3	1	2	3	0	0	8	11	19	18	0	1
Spanish House	5	2	3	2	5	1	5	1	0	0	18	6	24	23	0	1
Random	14	13	14	10	17	7	13	5	0	0	58	35	93	93	0	0
Senior House	27	27	7	11	27	29	40	12	0	0	101	79	180	183	5	2
500 Men. Dr.	39	40	40	60	69	49	49	26	2	0	199	175	374	352	0	22
TOTAL	341	334	320	345	477	254	424	247	7	0	1569	1180	2749	2630	6	125
	675		665		731		671		7		2749					

THE OFFICE OF MINORITY EDUCATION

The cumulative experience of the staff of the Office of Minority Education (OME) was reflected through the improved quality of programs and the expansion of services during the 1987-88 school year. Student demand for services increased this year due in part to: (1) a larger minority student population; and (2) the visibility and quality of services offered through the office. The OME staff not only improved services to minority students, but also became more involved in Institute programs and committees which, in turn, contributed to the quality of life for all students. Every new or expanded role taken on by staff members not only introduced more MIT personnel to the services of the Office but also added new perspectives and potential resources for the staff to utilize in some way to the benefit of the students we serve.

Here are the highlights of a very productive year:

OME/Department Liaisons

Introductory visits to the undergraduate officers or department chairpersons continued this year and generated new partnerships to enhance minority student matriculation at MIT. The benefits of these liaisons were evident through increased contact with undergraduate officers and a doubling of joint efforts to support students over last year. Such partnerships continued to be at the heart of our efforts to retain a greater percentage of minority students, and to improve their experience at MIT.

Research and Evaluation

The OME staff was pleased to welcome and work with the new Assistant Dean for Research, Dr. Alberta Lipson, who joined the Office of the Dean for Student Affairs in October of this year. Alberta has been working very closely with OME staff to learn about our programs and services so that she can assist the Office in carrying out its research responsibilities. She is currently working on the following research projects:

Evaluation of Project Interphase '88 - an eight-week summer enrichment program designed to provide entering minority students with an in-depth exposure to the subjects, Institute resources, and the pace and pressure of MIT. This program, in its twentieth year, has not been evaluated in a formal way, although its performance has been carefully monitored by administrative staff through the years. The research design that will be used involves studying Interphase '88 students over their first two years at MIT, comparing them to a comparable group of non-Interphase minority freshmen. Students will be surveyed at the beginning of Interphase, at the end of Interphase, at the end of the first and second semesters of the freshman year, and at the end of the sophomore year.

The study is in process now. A comparison group of students has been selected. The first two questionnaires are being developed and the research proposal is nearing completion.

Follow-up Study of Interphase Graduates - two follow-up studies of Interphase graduates to be conducted during the fall term. First, students who are in their sophomore, junior, and senior years will be surveyed to determine how helpful Project Interphase has been over time. Second, students who are no longer at MIT, including both those who have graduated and those who have withdrawn, will also be surveyed to determine how useful the Project Interphase experience has been and the possible effects that it has had on their post-MIT lives and careers.

Retention Studies - collecting information on OME programs and Institute activities which may influence the quality of life and the experience of underrepresented minority students at the Institute. We anticipate conducting both short and comprehensive studies once appropriate baseline data have been obtained.

A Study About Academic Performance - currently undertaking a pilot study to examine factors which affect academic performance of underrepresented minority students. We anticipate conducting a more comprehensive examination of this topic once the pilot study is completed.

Needs Assessment of Hispanic Students - currently in the planning stage of a quality of student life survey for Hispanic students. We will be examining the results of a pilot study and developing a research proposal and questionnaire this summer. The questionnaire will be sent out in the Fall 1988.

Alberta has also assisted us with the evaluation of the experience of Native American students, and with a study of minority student participation in UROP being conducted jointly with the Office of the Dean for Undergraduate Education.

ODSA/OME Collaboration

This year, the section heads of the ODSA and the Director of OME spent more time in planning and implementing collaborative efforts with each other than in the past. The OME staff was more involved than ever in major programs of each of the other offices, and ultimately more underrepresented minority students were involved in ODSA and Institute activities. The importance of such planning cannot be overemphasized because it is critical that all students, and especially minority students, feel and believe that Institute activities and offices are welcoming and supportive of them.

Student Leadership

A marked difference in the number of students involved in the life of the campus occurred this year. Minority student involvement in leadership activities this year in residential life programs, student governance, institutional committees, and student organizations was much greater than last year. A higher level of involvement with OME was also evident from greater student initiative in the student advisory committee to OME, the number of students requesting OME assistance in attending professional engineering and science conferences, and increased interest in working for OME, especially in Project Interphase.

Here are some examples of student involvement in more campus activities:

- Several Black students ran for elective offices in student government, including Undergraduate Associate President and Vice President. One was elected class president while another was elected to chair the Student Finance Board.
- Latino students raised money and organized PACHANGA, the east coast Thanksgiving conference for Chicano students attending Ivy League schools. The conference addressed educational and political concerns of students in higher education and attracted approximately 300 students.
- An alumnus, Lisa Martinez, supported the registration and transportation for five Latino students and an advisor to attend the regional meeting of the Society for Professional Hispanic Engineers.
- The Black Students Union and the Black Graduate Students Association co-sponsored several Roundtable Discussions at lunch time to explore pertinent issues affecting the lives of MIT students. Guest speakers included alumni, faculty, and staff as well as former MIT presidents.
- Two Native American students attended the annual spring leadership conference in Montana sponsored by the American Indian Society for Engineers and Scientists.

Students have been excited about their new ventures and have come to OME with new ideas (and a new energy) for becoming more involved in Institute activities.

The OME staff have been influential in supporting many of these new ventures, and continue to encourage student involvement in Institute activities.

OME Programs

The Tutoring Program (TP) attracted a larger number of students than last year. Publicity through a variety of sources, including the OME newsletter, The Tech, the UAS Freshman Newsletter, and the grapevine account for the increase in the participation in the TP. Students using the TP are primarily freshmen and sophomores.

The Strategies and Secrets for Academic Success Seminars (SSAS) were quite successful again this year. Five sessions were held and were particularly meaningful because of the greater number of faculty who participated in each session. The discussions were lively and the interactions fostered new relationships between students and faculty.

Project Interphase. Faculty members of the Project Interphase Subcommittee of the OME Advisory Board revised the curriculum to better meet the needs of students. For the 1987-88 program, the physics laboratory was revised and continued for a second year; it proved to be quite popular with the freshmen. (In fact, it was such a hit that Professor Jonathan King also offered it to all freshmen during IAP '88.) In Interphase '88, this was an eight-week laboratory that students attended for three hours a week.

A new Chemistry laboratory was offered by Professor Alan Davison to complement his Chemistry lectures. This two-hour laboratory was held in the evenings for four weeks.

Staff Changes

Anthony Canchola-Flores became more heavily involved with advising and counselling students, and represented OME on several ODSA and Institute committees. He was also promoted to Assistant Dean for Student Affairs, a well-deserved honor.

Dallas Slawter resigned her position as Assistant to the Director in January, 1988 to take a position at Boston University Medical Center. Her successor, Maria Rodrigues, came to MIT with several years of experience in finance and accounting.

Donna Marie Horse Grant, a consultant to the OME, has been involved with the Admissions Office in recruiting Native American students. She attended the National Indian Education Association's annual meeting, and represented MIT at their college information booth. In addition, Donna Marie is completing an assessment of Native American students' experiences at MIT.

FALL 1987 ENROLLMENT STATISTICS FOR UNDERREPRESENTED MINORITY STUDENTS

	Native American	Black American	Hispanic American	Minority Total	All Students	% Minority
Undergraduates	15*	219	189	423	4377	9.7
Graduates	3*	75*	44	122	5188	2.4
Total	18	294	233	545	9565	5.7

*decrease from last year.

JOYCE T. GIBSON
ANTHONY CANCHOLA-FLORES
MARIA E. RODRIGUES

CHAIRMAN OF THE FACULTY

The Faculty Policy Committee

Early in the 1987-88 year, the Faculty Policy Committee found that its agenda was extremely full, and growing, because of several developments within MIT. The Committee devoted most of its time this year to three areas: 1) formulating amendments to MIT's policy on showing pornographic films, 2) dealing with issues raised by the closing of the Department of Applied Biological Sciences, and 3) working with the Committee on Faculty-Administration toward the establishment of an ad hoc committee on family and work issues.

Proposed amendments to the policy on pornographic films: The Committee on Discipline expressed reservations about MIT's policy on showing pornographic films, and FPC was asked by Academic Council to review the policy and make recommendations for changes. The Committee heard from Dean of Student Affairs Shirley McBay and representatives from her office; Dr. Mary Rowe, special assistant to the President; and Professor Paul Joss, chair of the Committee on Discipline. Background on the current policy was gathered, and discussions were held to determine areas that could be changed. Issues such as freedom of speech, the rights of minorities, and the advisability of having such a policy and its defensibility were debated at length. Faculty Policy Committee members believed that MIT should continue to regulate the times and places for showing pornographic films, but favored several changes in the existing policy.

Proposed changes to the policy are: 1) all films can be shown in classrooms, lecture halls, and Kresge Auditorium at any time except during registration day or during R/O Week; 2) common areas within dormitories should not be available as theaters for pornographic films; 3) the review criteria need clarification to reflect concern with films that present the physical abuse or degradation of women as sexually exciting and acceptable, and that have no redeeming social, artistic, political, or intellectual value; 4) the screening committee should invite members of the MIT community to attend its review of films (this would also serve the purpose accomplished by a requirement for advance notice, and the screening committee could be held to a three-week limit for reaching a decision). The Faculty Policy Committee outlined a mechanism for handling requests to show pornographic films. Its report was distributed to the Faculty and discussed at its February meeting. Academic Council is now considering the policy and proposed changes.

Closing of the Department of Applied Biological Sciences: Initial discussion of this topic focused on procedures followed by the Administration prior to the decision to close the Department of Applied Biological Sciences, the meaning of tenure for an MIT faculty member, and the effect of the decision and its aftermath on the careers and morale of ABS faculty, staff, and students. The role of the Faculty Policy Committee was also discussed.

Professor Frieden met with the head and other members of Applied Biological Sciences to learn the background of the decision and to find out what progress was being made toward relocating faculty members. Provost John Deutch briefed FPC on these matters as well.

Professor Frieden then invited Professor James Fay, head of the Committee on Faculty-Administration, to work closely with FPC in monitoring progress toward resolving ABS issues and to offer additional help to ABS faculty with their reassignment or other problems.

Following presentations by Professor Frieden to Academic Council and the MIT Corporation, FPC began to work with the President, Provost, and Committee on Faculty-Administration toward defining a mutually acceptable set of procedures that would guide future departmental reorganizations or closings.

The March faculty meeting adopted a resolution sponsored by ABS faculty calling on the President and Chair of the Faculty to appoint a faculty committee that would analyze the process used in closing the ABS Department and propose guidelines for future reorganizations or closings. This committee was appointed, with Professor Sheila Widnall as chair, and reported its recommendations to the May faculty meeting. These recommendations, which were endorsed by the faculty, call on FPC and the Administration to prepare an explicit statement for Institute Policies and Procedures spelling out the steps to be followed in reorganizing or terminating an academic unit; and a statement formalizing the principle that tenure is held in the Institute rather than in a department. The recommendations also call on FPC to review existing rules and policies on the initiation and termination of degree programs with the aim of establishing a single policy statement in Rules and Regulations of the Faculty. These recommendations will constitute a major part of the FPC agenda in the fall of 1988.

Ad Hoc Committee on Family and Work: Professor James Fay, chair of the Committee on Faculty-Administration presented his committee's concerns about the ongoing Strategic Review of Benefits and the need for a committee to focus on career and family issues. The charge to such a committee was discussed, and the President and Chair of the Faculty appointed a committee in June, chaired by Professor Peter Elias.

Other significant topics considered by the Faculty Policy Committee include:

- Professor Margaret MacVicar, Dean of Undergraduate Education, reported on the activities of the Committee on the Undergraduate Program and the current review of MIT's undergraduate program. Key themes underlying CUP's work are: 1) consonance of the first year with the rest of the undergraduate program, 2) integration of the General Institute Requirements with major programs (whether the GIRs are viewed as preprofessional or foundational), and 3) how the program balances the special MIT science-based education with liberal arts studies. CUP expects to review the science core, the Science Distribution Requirement, the first-year program, and IAP.
- Dr. David Wiley, Registrar, brought to FPC's attention the fact that Rosh Hashanah (the Jewish New Year) and fall 1988 Registration Day occur on the same day. To accommodate observance of the holiday, Dr. Wiley recommended registration alternatives. The Faculty Policy Committee solicited views from departments and proposed that alternative registration days be designated.
- The Tent City/homeless crisis spilled over to the Faculty Policy Committee when two activists unexpectedly dropped in to one of its meetings. They asked to meet with the Committee to discuss faculty involvement in the homeless issue, but subsequently agreed to meet with a subset of the Committee at a later date. This occurred, and the students were advised that established complaint channels at MIT were appropriate for their grievances.
- A review of the Committee on Discipline and its procedures was begun, coordinated by Professors Jay Keyser and Kim Vandiver. The heavy load of COD, its difficulty in hearing cases in a timely manner, and the type of cases the Committee hears will be the focus of this review.

Other topics discussed during the year include: 1) IAP, 2) adjustments to the Writing Requirement, 3) NCAA drug-testing, 4) faculty involvement in approving degrees and closing curricula, 5) amendments to Rules and Regulations of the Faculty, and 6) possible disruptions at Commencement.

The Committee thanked two departing members -- Professors Peter Elias and Kim Vandiver -- for their participation and efforts, congratulated Professor Henry Jacoby on his election as the Chair-elect of the Faculty, and welcomed three new members, Professors Lotte Bailyn, Robert Fogelson, and Mary Lou Pardue.

Committee on the Undergraduate Program

The Committee on the Undergraduate Program (CUP), chaired by the Dean for Undergraduate Education, had an extremely busy year and addressed a number of issues. Significant among them were the following:

- Consideration of IAP in relation to its original goals and new directions it might take. CUP agreed to look at overall calendar issues and endorsed as a two-year experiment: 1) the addition of a spectrum of credit-bearing activities, and 2) a planning and evaluation process for departments and students, particularly freshmen;
- The final report of the School of Science Education Committee;
- Charging a committee, chaired by Professor Kenneth Manning, to examine the first-year program -- in particular, alternative pathways through the first year and the current pass/fail system. The report from the Committee on the First-Year Program was received in June 1988;
- Maintaining close contact with the Science-Engineering Working Group, co-chaired by Professors Robert Silbey and David Wormley, charged with facilitating coordination between the Schools of Engineering and Science in three areas: 1) the relationship between the first-year science and mathematics subjects and the engineering course curricula, 2) the possible need for science offerings beyond the first-year level, and 3) the need for biology education and its introduction into the engineering curricula;
- Charging a subcommittee to review faculty participation in Institute educational and policy activities with a goal of improving the system of equalizing faculty involvement across the five schools.

The Committee heard reports on the following topics: 1) the implementation of the new HASS Distribution Requirement and the optional minor in HASS, both voted by the Faculty in May 1987; 2) adjustments to the Writing Requirement including transferring responsibility for Phase Two to departments; 3) concerns of undergraduate student officers for various educational issues including those outlined in the Report of the Ad Hoc Student Committee on the First Year; 4) the progress of implementing new Context courses; 5) program assessment of Project Athena; and 6) calendar issues raised by the Registrar.

A two-day CUP winter work-session was held in January, focusing on the interrelationships of the General Institute Requirements and the departmental component of the overall four-year program, the intellectual rationale for General Institute Requirements, recognition of education activities in a faculty career, a progress report from the Committee on the First-Year Program, the profile of the admitted class, and reflections from first-year science core instructors. The sessions were well-attended and sparked intense discussion.

During the year, CUP brought together groups of people with varying views on many topics. The Committee synthesized these viewpoints in an attempt to crystallize its agenda for the next 18 months. CUP members agreed there is much to do and expect a full agenda again next year.

Professors Lee Grodzins and Robert Silbey completed their terms, as did student member Nat Seshan. Mr. Michael Behnke, Director of Admissions was a guest of CUP for 1987-88.

Other Faculty Committee Reports

Chairs of the Faculty committees have submitted summaries of the major agenda items addressed during the past year:

The major portion of the work this year for the Committee on Academic Performance (CAP) was devoted to the normal duties of the committee: handling petitions, deciding on undergraduate student actions, etc. One special effort addressed the problems associated with evening exams. Extensive discussions occurred within the Committee; a student survey was taken; feedback from deans, other MIT committees, undergraduate officers and student representatives was solicited and received. No "obviously best" course of action resulted and the CAP did not make any explicit decision on what to do. It is expected that the evening exam debate will be continued next year until some conclusion is reached.

The evolution of the undergraduate curriculum is leading to increased interaction across departmental and school boundaries. The Committee on Curricula (COC) spent much of its time developing procedures to ensure that all interests are properly represented in cross-disciplinary programs. Significant attention was given to issues concerning Context Courses; the realignment in the Humanities, Arts, and Social Sciences programs; issues attendant to the cancellation of existing curricula; and the clarification of some old questions regarding ROTC credit. The Committee is currently engaged in the codification of its current common-law procedures for distribution to those proposing curricular changes.

The Committee on Discipline (COD) adjudicated a number of grievances against students brought to the Committee by members of the MIT community. In addition, the Committee Chair has submitted to the Faculty Policy Committee a set of proposed revisions to the rules and regulations of COD. The purposes of these revisions are to facilitate a timely hearing of charges against an accused student and to enhance the protection of the due-process rights of accused students.

The Committee on Faculty-Administration (CFA), at the request of the Chair of the Faculty, met with the Administration committee conducting a strategic review of the benefits program to review its progress on issues affecting faculty. CFA determined that several benefits issues, such as child care, required more detailed consideration than CFA could give to it and that many of the benefits problems were related to each other through their impact on family responsibilities of faculty during a lifetime career. Encouraged by the stimulating discussion of this issue by the Women's Faculty group, CFA requested the Chair of the Faculty to consider the appointment of a special committee to study the issue of family and work in general and to focus in particular on the corresponding aspects of the benefits program. As a consequence of further discussions with the Faculty Policy Committee and the Administration, a Committee on Family and Work was appointed by the Chair of the Faculty and the President.

Also at the request of the Chair of the Faculty, the CFA Chair met with members of the Department of Applied Biological Sciences to discuss the matter of faculty interest in the reassignment of faculty to other positions. As a result of subsequent committee discussions, CFA developed its views on the

character of faculty appointments as it relates to the termination of academic programs. These views were communicated by the Chair to the special faculty committee reviewing the matter of the ABS department.

The Committee on Industrial Liaison, working closely with the Industrial Liaison Program (ILP) and the Treasurer, catalyzed a significant change in mission of the ILP. Henceforth, the ILP's principal objective will be to maximize the range of all productive contracts between faculty and industrial groups. These will include, in addition to the traditional liaison efforts, new activities aimed at developing major research and educational activities between companies and faculty. We all look forward with enthusiasm to this new, more productive role.

While the Committee on the Library System discussed a wide range of issues this year, the focus of activities related to three areas. First, the Committee reviewed and discussed the Library's acquisition budget. Second, Committee members met with the Corporation's Visiting Committee for the Libraries. Discussions indicated that the Committee's activities are consistent with comparable universities and seem quite appropriate. Finally, detailed discussion focused on the funding problems for serials and periodicals. While this issue may yet surface as a major funding problem, the Committee feels that appropriate actions are being taken and the Library administration is pursuing a decision process that should effectively involve the Faculty.

The agenda items for the Committee on Nominations were to fill the vacancies on the faculty committees (as always) and to choose a Chair-elect of the Faculty. Through heroic efforts, the Committee managed to finish its duties before the April faculty meeting at which the list was presented. The Faculty approved it at the May meeting. "[We] have done the state some service, and they know't" (W. Shakespeare, Othello, act V).

The activity of the Committee on Outside Professional Activities was typically quiet again this year. The Committee received one inquiry from the Engineering School Dean's Office regarding possible conflict in an appointment in which the potential appointee desired to maintain an outside commitment. This matter was resolved through telephone conversations and upon checking with various grey beards knowledgeable in the area of personnel policy in the past and found not to present an obstacle to the appointment sought by the School of Engineering.

Among the many issues discussed by the Committee on Student Affairs (CSA) during the year were the following: 1) Stress within the MIT environment, its consequences, and what might be done to alleviate it. This is an especially high-priority issue in view of the recent student suicides and suicides of members of the community in general. A subcommittee was formed to focus on this topic, but was not able to arrive at any recommendations concerning this highly complex topic in this short time. It is anticipated, however, that this study will continue throughout the following years and that the committee will be working in close collaboration with all other Institute bodies concerned with this and related issues.

2) Sexism on campus and how it affects not only our female students, but our community in general, and what steps might be taken to correct this situation. A second subcommittee was formed to look into this many-faceted problem. At this time, however, the committee has identified an immediate concern -- inadequate housing for female students. The present situation is not healthy, and continued study in the search for solutions should be pursued.

3) Related to item 2, the showing of pornographic films on campus was discussed by the entire committee, and a response to the Report from the Faculty Policy Committee to the Academic Council: MIT Policy on Pornographic Films was submitted to the Chair of the Faculty.

During the past year, the Committee on Undergraduate Admissions and Financial Aid (CUAFA) received regular reports from the Directors of Admissions and Financial Aid. Two financial aid policies were discussed in depth: the self-help level and outside scholarships. The Committee expressed to the President its hope that the self-help level can be maintained as low as possible. The Committee also recommended that MIT change its outside scholarship policy to permit students to receive a portion of the scholarship without reduction in MIT grant.

CUAFA met with faculty and administrators responsible for programs affecting minority undergraduates. The Committee was heartened to see the energy and commitment of these efforts, particularly now that the number of minority undergraduates is at an all-time high. The committee met with leaders of the undergraduate students and learned that among their concerns is the impact of term-time work on the education of needy students. CUAFA is planning to return to this issue next year in greater depth.

Finally, CUAFA discussed how to evaluate admissions and financial aid policies in a way that transcends the conventional numerical indices and provides a meaningful window on an increasingly diverse student population. The committee met with representatives from the Deans' offices (Undergraduate Education and Student Affairs) and from the Math and Physics Departments. CUAFA found that any analysis of admissions criteria and its effect on student performance must take into account high school preparation and the adequacy of teaching resources, particularly for recitation sections, at MIT. CUAFA concluded that its need for evaluation parallels the needs of those involved in formulating initiatives and reforms in MIT's undergraduate education.

The Committee on the Writing Requirement found itself quite busy this year. The Committee reported to the Faculty on guidelines for the transfer of much of the responsibility for the administration of Phase Two to individual departments. In addition, procedures were established to ensure that students complete Phase One of the Requirement by the first semester of their sophomore year and Phase Two by the first semester of their senior year. A written report was formally submitted to the Faculty last spring and was accepted at the April 1988 faculty meeting.

A significant portion of the year's effort was directed toward monitoring departmental plans for Phase II. Individual meetings were conducted with each Departmental Writing Requirement Coordinator and other interested faculty to discuss and review their procedures for establishing and administering Phase II options. The Committee also explored changing the format of the Freshman Essay Evaluation.

The Committee is happy to report that all but two members of the Class of '88 completed the Requirement and graduated. Both students who did not graduate are revising papers for September graduation.

The Harold E. Edgerton Faculty Achievement Award Selection Committee received eight nominees and selected Peter Perdue of the History Faculty. The Committee felt that a larger number than eight of the untenured faculty must be qualified candidates, and suggests to the next Committee that a more ambitious publicity campaign might be advisable in the future.

The James R. Killian, Jr. Faculty Achievement Award Selection Committee solicited nominations for the award from the entire MIT faculty. It then obtained supporting documentation for the nominations and considered these carefully. The award was voted to John S. Waugh, Arthur Amos Noyes Professor of Chemistry in the Department of Chemistry, for his leadership and outstanding contributions to the field of nuclear magnetic resonance. These contributions improved the theoretical foundations of nuclear magnetic resonance as well as the range and power of its applications.

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: the late Fred C. Schweppe (Academic Performance), Lawrence M. Lidsky (Curricula), Paul C. Joss (Discipline), James A. Fay (Faculty-Administration), Richard L. de Neufville (Industrial Liaison), John C. Henderson (Library System), Robert J. Silbey (Nominations), J. D. Nyhart (Outside Professional Activities), Richard K. Yamamoto (Student Affairs), Keith D. Stolzenbach (Undergraduate Admissions and Financial Aid), Jefferson W. Tester (Writing Requirement), John S. Waugh (Edgerton Award Selection Committee), and Richard S. Eckaus (Killian Award Selection Committee).

Bernard J. Frieden
Laura B. Mersky

SCHOOL OF ARCHITECTURE AND PLANNING

Fresh assessments of the direction and support for education and research characterized the School's development during the past academic year. Special attention was given in each academic division of the School to new patterns of responsibility to strengthen the educational mission.

The Department of Architecture reconfigured its organization of responsibilities to reflect more richly the complexity of its discipline and its offerings. The Department of Urban Studies and Planning developed guidelines for a more equitable distribution of academic responsibilities across the Department. The newly-designated Media Arts and Sciences Section established procedures for faculty participation in the future development of the Section.

The search for a new department head for the Department of Architecture was a particularly absorbing task this past year. After a rigorous review of a great many potential candidates from the ranks of practitioners and educators outside the department and visits by a selection of these individuals, the search was concluded without making an appointment. Subsequently, Professor William Porter agreed to serve as department head for a regular term commencing in July 1988. The department's professional degree program was recently reaccredited for five years by the National Architectural Accrediting Board. The NAAB report was perceptive and very supportive.

During the year the School defined stronger roles in a number of key Institute-wide activities. Of critical importance to the School is undergraduate educational reform and in particular the development of more vigorous programs in the creative arts. In response, the Department of Architecture prepared an initial plan for expansion of visual studies in the School. A report, prepared under Professor David Friedman, calls for the introduction of a foundation subject in the visual arts, which prepares undergraduate students to pursue more advanced work across a wide set of specialized areas of artistic endeavor, including film/video, photography, machine-based graphics, art history, environmental and performance art, drawing and painting, sculpture, and industrial design. The implementation of these ideas will be directed by a newly-appointed senior faculty member.

Research activities in the School included the steady growth of funding for building technology and the management of building portfolios, as well as a major grant from Citibank to examine the financing of real estate development. The affordable housing research, funded by the Ford Foundation, concluded with the publication of an important collection of policy papers. In the Media Laboratory the volume of research activities continued to grow at a strong rate to reach an annual volume of \$5.7 million.

The School fashioned two new awards programs. The Lawrence B. Anderson Award will be given every two years to a former School member for support of a documentation project. The first award was made to Alfonso Govea, SM Arch S 1977, an architect in Mexico City, for his innovative proposal to document 20th century housing types in Mexico City. Fundraising began for the Kevin Lynch Award, which is intended to support an annual award to the author of a significant publication in the area of environmental design, as well as purchase of environmental design materials for Rotch Library.

In November the Visiting Committee to the School of Architecture and Planning met in three subcommittees corresponding to the academic programs. Chairman Normal Leventhal reported to the MIT Corporation that the Committee in its review of the School's programs found notable progress since the last visit in 1985, especially in the Department of Architecture. The Committee urged the School to overcome the gap for students who want to work at the interface between planning and architectural design, and to take full advantage in both departments of new opportunities to expand undergraduate education.

Faculty

The maturing of policy directions in the visual arts and in the area of building technology,

along with usual faculty changes, intensified search effort across the School. Two new appointments were made in the history of art and two in building technology; one is forthcoming in the visual arts. A new assistant professor appointment was made in urban studies in the area of quantitative research methods. In media arts and sciences a new assistant professor appointment was made in the field of film/video and searches were continued to fill a further set of faculty appointments.

Facilities

Improvements to the School's physical facilities included modifications to the Wiesner Building to respond to new Media Lab research projects; the completion, with the support of Project Athena and a grant from the Dean of the School of Engineering, of an "electronic classroom" associated with the Computer Resource Laboratory; and schematic plans by a team of students for renovation of the fourth floor, Level 1 studios.

Of vital importance to the School was progress in the design of the improvements and extension to Rotch Library. The Boston architecture firm of Schwartz/Silver was appointed and worked intensively with the client team to develop this \$6 million project, which includes a 21,000 g.s.f. addition and renovation of the existing 9,000 g.s.f. facility. The Provost committed \$3 million of Institute funds for Rotch, and funding applications were made to outside sources with a view to starting construction early in 1989.

Administration

Modifications to the School's decision structure in two key areas will be implemented in September. Four senior faculty members will be added to School Council to consider and recommend faculty appointments and promotions. Membership of School Council will also be enlarged by the presence of the chairperson of a newly-appointed School-wide Affirmative Action Committee, which will oversee the affirmative action component of searches and appointments and recommend ways to enhance the School's ability to attract women and underrepresented minorities. In April 1988 the membership of the School Council was enlarged by the addition of the director of the Center for Real Estate Development.

Community Composition

Of the School's total enrollment of 574 students, 214 were women, 54 were underrepresented minorities, and 165 were from other countries. The number of undergraduate majors in the Department of Architecture continued to grow strongly, and is expected to total 130 in the fall of 1988. The Department of Urban Studies and Planning continued its aggressive recruitment of minority students for the MCP program and also made special efforts, recognized throughout the Institute, to ensure that the greatly increased number of minority students in the department find a congenial environment. Of the 75 School faculty, 12 are women and 5 are minority members.

JOHN DE MONCHAUX

FACULTY, OTHER ACADEMIC STAFF, AND RESEARCH STAFF -- 1987-1988

	1986-1987				1987-1988			
	Total	Full Time Equivalent	Women	Minority	Total	Full Time Equivalent	Women	Minority
<u>Department of Architecture</u>								
Faculty	35	34	5	--	25	23.45	3	--
Other Academic Staff	40	19.5	7	2	39	18.9	7	1
Research Staff	13	12.1	2	--	2	1.5	0	0
Without Pay	15	14	3	--	6	4	1	--
<u>Department of Urban Studies and Planning</u>								
Faculty	27	24.75	4	4	27	25.5	5	4
Other Academic Staff	18	10.2	3	2	19	10.25	5	2
Research Staff	1	1	--	--	1	1	--	--
Without Pay	10	7.7	5	5	11	6.5	7	
<u>Media Arts and Sciences Section</u>								
Faculty					13	13	3	0
Other Academic Staff					7	5.7	2	0
Research Staff					0	0	0	0
Without Pay					6	3	1	0
<u>Laboratory of Architecture and Planning</u>								
Faculty	--	--	--	--	--	--	--	--
Other Academic Staff	1	.20	--	--	--	--	--	--
Research Staff	7	5.25	3	--	2	.40	1	--
Without Pay	14	7.15	1	--	19	9.95	1	--
<u>Media Laboratory</u>								
Research Staff	16	13.02	2	-	18	16.62	3	1
Without Pay	18	16.5	1	0	25	19.9	3	--
<u>School Totals</u>								
Faculty	62	58.75	9	4	65	61.95	11	4
Other Academic Staff	59	29.9	10	4	65	34.85	14	3
Research Staff	37	31.37	5	0	23	19.52	4	1
Without Pay	57	45.35	10	5	67	43.35	13	7

STUDENT ENROLLMENT AND COMPOSITION 1987-1988

	<u>Total</u>	<u>Women</u>	<u>Minority</u>	<u>International</u>
<u>Department of Architecture</u>				
Undergraduate	110	53	8	6
M.Arch.	97	29	4	17
S.M.Arch.S.	68	17	0	47
S.M.Vis.S.	9	1	0	3
Ph.D. (resident)	10	3	0	4
Total Graduate Resident	184	50	4	71
S.M. Real Estate Devel.	19	9	0	1
Ph.D. (nonresident)	13	4	0	6
Special Students (nondegree)	2	0	0	1
ARCHITECTURE TOTALS	328	116	12	85
<u>Department of Urban Studies and Planning</u>				
Undergraduate	2	0	1	0
M.C.P.	78	41	37	25
M.S.R.E.D.	17	6	1	1
Joint M.C.P./M.Arch.	3	1	0	3
Ph.D. (resident)	35	13	2	13
Total Graduate Resident	133	61	40	42
Ph.D. (nonresident)	34	18	1	16
Special Students (nondegree)				
SPURS	17	4	0	17
CFP	0	0	0	0
DUSP TOTALS	186	83	41	75
<u>Media Arts and Sciences Section</u>				
S.M. (unspecified)	37	8	1	4
Ph.D.	20	5	0	1
Special Students	3	2	0	0
MAS TOTALS	60	15	1	5
<u>School Totals</u>				
Undergraduates	112	53	9	6
Graduate	317	111	44	113
Special Students	145	50	1	46
<u>TOTAL ENROLLMENT</u>	574	214	54	165

Department of Architecture

The department is in a very strong position to address architectural education in a humanistic, technological and global perspective. We have achieved excellence in some areas, and we already have broad coverage that would enable us to make these concerns felt at each level of education: undergraduate and graduate, both professional and research. The most important objective for the department is to realize this potential.

This has been a year of building and rebuilding in which internal issues of department governance, including special urgency about balancing the budget, were addressed. Sessions with the Corporation Visiting Committee in the fall and the National Architectural Accrediting Board (NAAB) early in the spring semester provided opportunities to articulate our objectives and the new management organization--and elicited positive response and counsel from both groups.

The department's governance organization was defined as a matrix of eight committees: five discipline groups arrayed opposite three committees representing department program groups. The discipline group committees are: Architectural Design (Professor Imre Halasz, chair), Building Technology (Professor Leon Glicksman, chair), History, Theory and Criticism (Professor David Friedman, chair), Visual Studies (Professor Friedman, chair pro temp), and Architecture Studies (Professor Ronald Lewcock, chair). Program committees are: Undergraduate (Professor Leon Groisser, chair), Professional (Master of Architecture and Master of Visual Studies, Thomas Chastain, chair), and Research/Advanced Study (SM Architecture Studies and PhD, Professor Julian Beinart, chair). The eight committees kept a schedule of individual meetings through the academic year and the matrix committee chairmen and the Head met bi-weekly as a group.

The committees were charged to address the issues of rapidly rising undergraduate enrollment; the diffusion of the second master's program into more parts unrelated to one another and to that program's research objectives; a substantial budget shortfall--importantly related to the first two conditions; and the Provost's charge to rebuild department visual arts teaching for MIT undergraduates. Specifically, discipline committees were asked to list subjects of instruction that serve the various programs and given faculty line and budget parameters to work within. Program committees were asked to detail sets of subjects needed to satisfy their degree requirements and to safeguard the interests of students being served by the department in their programs.

The matrix committees made reports at the end of the academic year with recommendations for actions within each individual group and in relation to each other.

PROGRAMS

Design, design theory, and design-related innovations from advanced study lie at the heart of the department. There are undergraduate and research programs in the department in addition to the professional Master of Architecture (MArch) program. This unusual arrangement at MIT means that architecture can be broadly defined. Students can study here in ways that should open up to them a much wider variety of careers in architecture than is commonly available through other departments of architecture.

Undergraduate enrollments continued a four year pattern of increase, from 70 in 1984 to 110, with indications that next year's numbers will be even larger. Diversion of teachers and supporting funds from other programs to the introductory subjects and beginning architectural design (Level I) studios created demand for significant reorganization and/or budget increases. Increasing undergraduate enrollment spurred the effort to broaden the undergraduate curriculum to accommodate more possible majors.

The undergraduate program committee has recommended that two additional streams beyond the pre-professional architectural design major be opened in the next two years: building technology, where four new undergraduate subjects will be taught next year and the new graduate MS program will have significant spin-offs for undergraduates; and theory history environment and method, a new stream that would draw on the faculty interests and resources already present in Research/Advanced Study (SMArchS and PhD) fields. Eventually a third stream in visual arts will be added as a major when the program is established. The undergraduate committee proposed that the pre-professional architectural design stream, which now enrolls almost all Course IV undergraduate majors, undergo some change as well, including requirement of one less design studio, one more introductory subject, and a final thesis.

The Professional program committee was chaired in the fall term by Professor Ranko Bon. Using the NAAB criteria as the basis for an appraisal, they studied subject offerings for MArch students by the discipline groups. Subsequently, the committee, chaired spring term by Mr. Chastain, recommended "platform subjects"

in four areas: building technology; history, theory and criticism of art and architecture; design methods and tools; and visual studies.

The Research/Advanced Study program committee has decreased the overall number of SMArchS students admitted for fall 1988 and worked to develop more important connection of the second master's streams to PhD fields. An MS degree in building technology has been approved by the Institute; two PhD students in the field will begin their studies this summer and formal approval of the PhD in building technology will be sought in the coming year. The department will also put forward a proposal for a doctoral field in "environment and method" at the same time as the building technology doctoral field is formalized on an interdisciplinary basis with engineering departments.

DISCIPLINE GROUPS

Architectural Design continued to work at diversifying the range of issues and approaches to design and studio teaching. The Distinguished Visitors Studio had a second successful year, hosting Ms. Reiko Tomita and members of Team Zoo from Japan, Gunther Behnisch, Helmut Schulitz, Manfred Sabatke from Germany, and Enzo Testa from Italy, as teachers in advanced design studios. Unfortunately, the need for radical downward adjustment of our budget puts the Distinguished Visitors Program in jeopardy.

The design faculty also explored methods and settings for the teaching of design. This year for the first time, undergraduates and graduate MArch students were taught in separate Level I studios in both the fall and spring semesters. The graduate Level I studio was especially energetic and productive, climaxing the year with a final review of their project for exhibition space for Larz Anderson Park, Brookline, in a full scale model built on the site. The experiment continues with the next set of new graduate MArchs in fall 1988.

History, Theory and Criticism (HTC) is a model discipline group for the matrix, having taken primary responsibility for its own faculty hiring, budget and subject generation for many years. Housing faculty in the history of art and architecture within a professional architecture program, HTC function as a bridge between the concerns of the discipline of art history and those of the architectural profession. The group provides a range of subjects for MIT undergraduates, for students in all of the department's programs, and for its own doctoral students. It is first among the department's discipline groups in reaching undergraduate students, teaching Humanities Distribution and other subjects with very large enrollments each semester.

Demand from the undergraduate and professional program user groups has significantly increased during the last couple of years. Renewed attention to undergraduate education at MIT has resulted in increased interest in humanities subjects such as art history; concurrently, a new program of undergraduate education in visual studies is being developed. Further, efforts within the department to strengthen the MArch program have shown the need for more HTC subjects that address professional students as the primary audience.

HTC conducted a search this year for a replacement for Professor Anne Wagner, the group's sole art historian. The group concluded, with Institute support, that demand in this area was sufficiently great that two positions were needed. Two new faculty members will therefore begin appointments in the coming year to teach undergraduate surveys, graduate seminars, and eventually subjects in criticism connected with a new undergraduate curriculum in visual studies. Professor Francesco Passanti developed a subject aimed at MArch students to address current critical issues in architecture, examining their impact on practice and exploring historical themes to which they relate.

As in the past, HTC offered a rich selection of distinguished visiting scholars. Ms. Michela Bandini of the Architectural Association, London, taught on Italian architecture and theories of modern architecture during the fall. Professor Barry Bergdoll, from Columbia University, an expert on French 19th century architecture, taught a seminar on Parisian urbanism during the spring. Also in the spring, Professor James O'Gorman from Wellesley College lectured on American architecture.

The Building Technology group, in cooperation with faculty in Mechanical Engineering, Civil Engineering and Materials Science, designed a new interdepartmental graduate (MS) program in building technology which was approved by the Institute this year. Several new undergraduate subjects have been developed and will be offered in 1988-89, including new offerings in building systems, building economics, energy in buildings and a building technology project laboratory.

A search was carried out for two new faculty members--one to teach subjects in the MArch and the MS in building technology programs, and one to teach the undergraduate building technology lab and advanced building technology subjects. Both new faculty members will be expected to carry out research in their areas of specialty. James Axley, who has expertise in structural engineering and whose current research is in the development of a new computational model for indoor air quality, has been identified for the first position; Lesley Norford, whose field is energy efficient technology in buildings and controls, will fill the second.

Professor Friedman served as chairman, pro temp, of the Visual Studies discipline group and took responsibility for two very important tasks: formulation of a new program for visual arts education at MIT,

(with Professor Passanti and Dean Lois Craig); and conduct of a search for a senior faculty member in visual arts. A senior artist and teacher/administrator was sought both to teach and lead the expansion and reinvigoration of undergraduate visual arts and tie the undergraduate curriculum to graduate programs in the visual arts. Search committee members were: Professors Passanti and Frank Miller (Architecture), Professor Muriel Cooper (Media Laboratory), Katy Kline (Director of the List Gallery) and David Pease, Dean of the Yale School of Art.

The Architecture Studies discipline group represents several fields of inquiry and research in architecture and offers subjects to undergraduates, professional and research students. The committee recommended that the advanced studies program be conceived as focusing on a strong central core of design theory and methods. Fields of specialization would form around the core relating especially to intercultural, environmental and methodological studies. They concluded that in order to obtain a unified advanced studies program, it would be necessary to weld together design and research throughout the department and that means must be devised to bring together the Architecture Studies and Architectural Design faculties.

FACULTY

Professor William L. Porter, who served as Interim Department Head this academic year, has agreed to accept appointment as permanent Department Head beginning in July 1988.

New faculty: Professor Passanti began appointment in the History, Theory and Criticism discipline group this year; Ms. Miroslav Benes was a Lecturer in HTC, teaching subjects in the history of landscape architecture; Professor Glicksman joined the department as a tenured professor of building technology.

Barry Zevin (March '73) and Yim Lim were appointed as Lecturers on the architectural design faculty. Jorge Andrade (SMArchS '81) was a Visiting Professor from the University of Mexico this fall, teaching Thematic Design: Methods. Fred Dubin, a prominent energy management consultant and President of Dubin-Bloome Associates, New York, was a guest lecturer in building technology.

Professor Yasser Tabbaa, Aga Khan Career Development Professor of the History of Islamic Architecture, has tendered his resignation and will take up a teaching position at the University of Michigan. Professor Wagner resigned to accept a tenured position in the Department of Art, University of California, Berkeley. Ms. Benes has accepted a position at the Harvard Graduate School of Design.

Professors Richard Filipowski and Waclaw Zalewski retired, effective the end of this year. Filip has been a teacher of visual studies in this department since 1952, Professor Zalewski has taught structures here for 23 years. Both will be greatly missed.

Professors John Myer and Rosemary Grimshaw (Architectural Design) were on leave for the academic year; Professor John Habraken (Research/Advanced Studies) was absent on leave in the fall term; and Professor Stanford Anderson (HTC) took sabbatical in the spring.

Professor Miller with Professor Patrick Purcell of the Media Laboratory planned and co-chaired a symposium on "Computers in Design--Emerging Research Directions" for SKOK Systems, Inc., in Chicago. In December, Reinhard Goethert and Nabeel Hamdi were invited to Quito, Ecuador to conduct a two-week workshop on site design for technical staff from various agencies throughout Ecuador. The workshop was jointly sponsored by the World Bank, the German Agency for Technical Cooperation (GTZ), and the National Housing Bank of Ecuador. Professors Beinart and Anderson participated this June in an international conference organized jointly by Seoul National University's Graduate School of Environmental Design and MIT's School of Architecture and Planning. The conference, titled "Hosting the Olympics: The Long Term Impact," provided a forum for the sharing of experiences of host cities through participation of scholars, planners, and policy makers from Pacific Rim countries.

Reinhard Goethert and Nabeel Hamdi were awarded a \$42,000 challenge grant by the Executive Office of Communities and Development, Commonwealth of Massachusetts. The award is given in cooperation with the Mass. Housing Partnership to groups and individuals who have developed innovative housing projects which can serve as models for similar developments. Edward Robbins was honored this year with the MIT Graduate Student Council Teaching Award.

OTHER

The third annual Arthur H. Schein Memorial Lecture was given in September by Joseph Esherick, distinguished practitioner from San Francisco, teacher and former head of the Department of Architecture, University of California, Berkeley. The Department Lecture Series featured talks by conceptual artist, Christo, and architect/teachers Ralph Lerner and Werner Seligmann among others.

The Special Interest Group in Urban Settlements (SIGUS) mounted a series of workshops again this year. The four, held from November through April, focused on exploring the theories and practice of community based design. Guest faculty leaders were: Colin Ward, John F.C. Turner, Rod Hackney, and Shlomo Angel.

Four MIT Architecture students won first prize in the Boston area in a design competition "Housing the Homeless" sponsored by the Boston Society of Architects in cooperation with the American Institute of Architects. The winning team included Neil J. Mongold (SMArchS '88), SMArchS students Daniel J. Glenn and Pablo H. Luna, and MArch student Laura G. Spark. Their plan will be exhibited in Boston and throughout the United States along with the winning entries of student teams from other regions. Philip R. Thompson (MArch'88) won the Robert Bradford Newman Award for excellence in the study of acoustics and its application to architecture. Thompson was one of five architecture students from departments across the US to be awarded the Newman Medal this year. The award was made possible by a fund established in honor of Robert Newman ('49), a member of this department's faculty for over 30 years.

Roberto Pietroforte (SMArchS '87) and Floris Panayides (SMArchS '88) received the Tucker-Voss Award which honors one or more promising students of building construction. Department awards to students were as follows: The Francis Ward Chandler Prize to Elizabeth Beliveau, Jose Sama, Kevin Thornton for achievement in architectural design; the William Everett Chamberlain Prize to Hani Asfour, Simone Tsignounis; the Sydney B. Karofsky '37 Prize to the outstanding student entering the final year of study for the MArch degree to Mahmood Faruqi; the Department Award for the outstanding SMArchS student in the final year of study to Lawrence Vale; the Alpha Rho Chi Medal for leadership ability and the promise of real professional merit to Christopher Lyon; the AIA Foundation Medal for the top ranking student graduating from the professional program equally to Julia Campbell and Denise Henrich.

WILLIAM L. PORTER

Department of Urban Studies and Planning

INTRODUCTION

This year the Department of Urban Studies and Planning has spent its time consolidating its activities and developing a sense of shared responsibility. Given a faculty of stable size with few changes over the next few years, our task was to look at our own strengths and interests, to find those which intersect with the problems of the world and then to construct a research and educational program to fit. Internally, our task was to develop a collegial and professional working environment.

Faculty Responsibility

In the fall, the entire faculty met to consider the findings of a small committee whose charge it was to compile all of the tasks of the department (teaching, research, student support, committees, commencement, IAP, etc.) and to establish norms so that the work load would be as fairly shared as possible. That meeting, on Thompson's Island, and several subsequent ones produced a consensus as to our respective responsibilities and has led to an annual work plan for each faculty member, which encompasses the expectations on each task. The faculty will continue to monitor and update the tasks, norms and work plans.

Support Staff

Community Day, also held in the fall, was organized by students, support staff and faculty to improve communications across the department. Among the outcomes were a workshop on Racism and the engaging of consultants to help develop a better professional working environment between faculty and support staff. The work so far has involved interviews and meetings, the setting up of a Working Relations Committee, and pilot projects in two of the curriculum sub-groups. We expect the work to continue to improve departmental working relations.

EDUCATIONAL PROGRAMS

The PhD program has achieved stability in the number of applicants and has again increased the number of graduates -- this year to 12. Professor Langley Keyes directed the program and continues to improve the collective, intellectual experience of the diverse entering students.

The Master of City Planning (MCP) program devoted a substantial amount of its energy in consolidating the specializations into four Curriculum Focus Groups (CFGs): Developing Countries/Regional Planning; Environmental Policy; Housing and Community Development; and Design and Development. The CFGs are intended as planning groups for consolidation of the department's faculty and course development into four broad areas that encompass several specifications. The faculty, students, and alumni of the CFGs have organized themselves to plan subject sequences, introductory subjects, thesis preparation subjects, advising loads, and to make connections to the world of practice. These activities will be elaborated upon in this coming year with the expectation that each CFG will eventually become a fully functioning sub-group in the department with its own coherent space. The number of applications increased slightly with continuing success in attracting minority applicants (45). Of these, 21 were accepted and, despite reduced funding, 15 will be joining the incoming class.

Although the number of undergraduate majors is only a handful, there has been a resurgence in the number of faculty engaged in undergraduate education -- in subjects, seminars, and advising.

The Community Fellows Program, under the direction of Adjunct Professor Mel King, sponsored four Fellows: Lauren Greene, Barbara Marshall, Mildred Noble, and Angela Perkins.

The Special Program for Urban and Regional Studies (SPURS), now under the direction of Senior Lecturer Alan Strout, hosted 18 Fellows from the following countries: Italy, Colombia, Pakistan, Venezuela, Nepal, India, Brazil, Nigeria, Turkey, Poland, Japan, Ethiopia, and Greece. The Program sponsored talks during the Tuesday evening and Wednesday luncheon seminars, and a field trip to Venezuela.

FACULTY

This year an era came to an end with the retirement of Professors Aaron Fleisher and Lloyd Rodwin. Professor Fleisher joined the department from Electrical Engineering and pioneered the use of computers, modelling and quantitative methods in urban planning. He will continue to work on his research in design methods as Professor Emeritus. Professor Rodwin established the importance of education in planning

for developing countries and will continue his extensive travels throughout the world to promote that cause.

Professors Bish Sanyal and Mark Schuster were promoted to Associate Professor. Lyna Wiggins, formerly at Stanford University's Civil Engineering Department, was appointed Assistant Professor with interests in Quantitative Methods and Environmental Policy. Assistant Professor Lauren Benton resigned in the spring.

The faculty, as usual, were involved in research, writing, practice, and community service. Some highlights follow:

- Professor Lawrence Bacow returned from the private sector to become Director of Research of the Center for Real Estate Development (CRED). Projects include research on foreign investment in United States real estate in a recessionary environment.
- Professor Philip Clay was on leave, teaching at Cleveland State University and writing on the future of Boston housing and on strategic planning for Cleveland.
- Associate Professor Joseph Ferreira directed the School's Computer Resource Laboratory and continued his research with the Athena Project.
- Lecturer Dennis Frenchman's firm won a national AIA award in Urban Design for their West Broadway Public Housing Master Plan. He was also one of the faculty in the joint Tsinghua-MIT Design Studio held in Beijing.
- Professor Bernard Frieden did yeoman service as Chair of the Faculty, ably and coolly handling the controversies over the closing of the Department of Applied Biology and those involving Tent City on the Simplex site.
- Professor Ralph Gakenheimer was on leave conducting research on infrastructure in developing countries.
- Professor Gary Hack was on leave working on the Westway in New York City, Children's Museum in Boston, and the redevelopment of the Prudential Center.
- Professor Bennett Harrison published his research on the Massachusetts economy in the Sunday Boston Globe and his book, The Great U-Turn: Rising Inequality and Falling Wages in America (with Barry Bluestone), will be out in September, 1988. He also started a Ford Foundation project comparing urban and rural labor markets.
- Professor Keyes, with Visiting Professor Denise Di Pasquale, coordinated a major grant from Ford and support from Robert Wood Johnson and other foundations to prepare a series of papers on future policy for low-income housing, including the paper they wrote on "Housing and the Homeless."
- Adjunct Professor King successfully organized the Jackson for President campaign in New England and continued his work with Youth Enterprises Development Corporation.
- Assistant Professor Merrie Klapp's book, Challenges from Smart Publics, is due out this summer.
- Professor Tunney Lee chaired a committee of the Massachusetts Executive Office of Communities and Development to examine public housing production and to recommend ways of expediting it.
- Assistant Professor Edwin Melendez has been awarded a Ford Foundation post-doctoral fellowship.
- Professor Donald Schön continued his NSF and NEA projects on Generic Design Processes and Design Notations.
- Professor Lawrence Susskind continued his work on public dispute resolution and published his book, Breaking the Impasse - Consensual Approaches to Resolving Public Disputes (co-authored with Jeffrey Cruikshank).
- Associate Professor Schuster conducted research on Arts and Urban Development and presented his work on cultural policy at several international conferences.
- Professor Gary Marx was on leave at The Center for the Advanced Study in the Behavioral Sciences at Stanford. His book, Under Cover: Police Surveillance in America, has been published by the University of California Press. Professor Marx has appeared on both Nightline and The Oprah Winfrey Show.

- Professor Judith Tendler published "Whatever Happened to Poverty Alleviation?" for the Ford Foundation and spoke at several universities and conferences on Third World poverty.

STUDENT AWARDS

William Tuttle received the AICP Outstanding Student Award; Ricanne Hadrian received the Charles Abrams Scholarship. Scott Cassel received the Klein Prize for Scientific and Technical Writing, and Miriam Maxian received the Urban Land Institute Award. The Flora Crockett Stephenson Award was received by Ann Greiner, Jean Kluver, Susan Podziba, and Rebecca Stevens for a paper they submitted as a group.

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 1987-88 academic year completed the 1985-88 fiscal cycle. It was marked by activities both old and new aimed at consolidating, extending and broadening the work of the Program. In November, Yudhishtir Isar left the Program to return to Unesco in Paris. On February 1, 1988, he was replaced as Director by Ms. Barbro Ek, who had previously served as Director of Programs in Southwest Asia and Islamic Civilization at the Fletcher School of Law and Diplomacy. 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. Substantial time during the spring semester was spent in preparing the budget for the 1988-91 fiscal cycle.

Faculty

AKP policy is made by an Executive Council currently composed of Professor Oleg Grabar (Chairman, 1987-88), Aga Khan Professor of Islamic Art and Architecture at Harvard, Professor Ronald B. Lewcock, Aga Khan Professor of Architecture and Design for Islamic Cultures at MIT, Professor William L. Porter, Professor of Architecture and Planning at MIT, and Professor François Vigier, Charles Dyer Norton Professor of Regional Planning at the Graduate School of Design, Harvard University. Other MIT faculty during 1987-88 included Professor Yasser Tabbaa (on sabbatical leave during the spring term), and Mr. Akhtar Badshah, Instructor/Research Associate in the "Design for Islamic Societies" unit of the S.M.Arch.S. program.

Academic Programs at MIT

Seven new students were enrolled in the two year course entitled "Design for Islamic Societies" leading to the Master of Science in Architectural Studies degree, taught by Professor Lewcock, assisted by Mr. Badshah, and with the participation of a number of visiting critics. Seven students already enrolled in the course brought the unit up to its normal strength of between fourteen and sixteen students at one time. The unit focuses its reflection and debate on both practical and theoretical issues in architecture which are characteristic of non-Western societies: appropriate responses to climate, building materials and building technology together with sociocultural attitudes and values which have a direct bearing on the relationship of man to his environment. The course encourages students to familiarize themselves with the architectural forms and structures found in traditional urban environments in the Islamic world and then to compare them with forms and structures which have been developed since the application of western ideas which have spread all over the world in modern times.

First year students work on a series of three workshops. The first workshop is concerned with familiarizing the students with the forms, functions and spaces of traditional Islamic and other non-western cities. In addition, the conservation, rehabilitation and the future of old central areas in rapidly expanding cities is dealt with; also, issues of clashing ideas in forms and functions; the inter-relationship of new and old, the accommodation of modernization -- motor traffic, parking, new building types, factors of social, regional and national identity, and the provision of housing and other facilities for the urban poor. In 1987 the old city of Sana'a was examined in the first workshop, as its problems exemplified many of these concerns.

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 in Asia and Africa with appropriate contemporary attitudes towards monumentality.

In 1987 students studied how the main square and the commercial spine had changed in one of the most historic cities in Indonesia, Yogyakarta. Proposals were made for interventions which might improve such elements of a city, involving research into its complex culture and strong traditional values.

The third workshop is 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 content to merely point to the direction of possible solutions. Faculty and students work closely together as a team, although finally certain ideas are explored individually or in small groups.

The spring term is devoted to a studio workshop which considers a specific architectural design in a rapidly changing traditional environment. In 1987 intrusions into the old walled city of Lahore, Pakistan were examined. The semester's work was preceded by a site visit to Lahore organized in collaboration with the architectural departments of the two institutions there. The DIS group was joined by the Bartlett School students and faculty as well as students and faculty from Dawood College of Engineering and Technology, Karachi and The National College of Arts, Lahore. The area of survey was the Shah Almi, an eighty feet wide commercial road cut into the otherwise dense fabric of the old city of Lahore. Thus a new central artery was designed by government planners as part of the reconstruction of an important area of the old city which had burnt out during the riots following partition in 1947. The task of the studio-workshop study was to understand not only the impact of the Shah Almi development on the walled city but also that of the truck and railway terminals on the surrounding areas. A proposed re-siting of the wholesale commercial activities, together with the reconstruction of single-storied parts of the Shah Almi, opens up opportunities for reassessment and for the proposal of new measures for intervention, which might redress some of the problems and introduce improvements which would benefit the eastern part of the old city.

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 take account of indigenous conditions, climate and appropriate building materials and theoretical approaches to creative activity in Islam.

Under the History, Theory and Criticism Program in the Department of Architecture, Professor Yasser Tabbaa offered a course on "Islamic Architecture to 1500" in the fall term as well as participating in another course on "Studies in Islamic Architecture" at Harvard with Professors Oleg Grabar and Gülru Necipoglu-Kafadar. Of the six AKP doctoral students in the Program, two were in residence at MIT completing course work, two pursued their historical study of architectural and urban form in Cairo and Istanbul, while the remaining two worked on completing their dissertations. One student received his Ph.D. degree with a dissertation topic on "The Rab' in Cairo: A Window on Mamluk Architecture and Urbanism."

Visiting Fellow

During 1987-88 the AKP welcomed two Visiting Research Fellows, Iraqi architect Dr. Subhi Al-Azzawi, who is completing a book on the courtyard houses of Baghdad and Ms. Serpil Bagci, who studied the image of Alexander the Great as it appears in Islamic culture, historiography, literature and painting.

Student Support

Tuition and living expenses for five doctoral students and 15 S.M.Arch.S. students were funded in whole or in part. Five students at Harvard and MIT were awarded summer travel grants for study trips to India, the Sahel countries, Yugoslavia, Indonesia, and Turkey.

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 Project, the AKP's visual documentation center entered a period of testing and evaluation of its prototype Images System which integrates database management and graphics with videodisc technology. Some 30,000 images of Islamic buildings are included in this innovative visual archive system which was placed at a number of locations at Harvard and MIT for user feed-back and evaluation. Indexing of images was further refined.

Seminars

Two AKP seminars, one academic, the other professional, were held during 1987-88. In November an international symposium on "Theories and Principles of Design in the Architecture of Islamic Societies" was held at MIT and attracted architectural historians as well as students and practitioners of architectural and urban design. It included presentations by leading architects and scholars from the Middle East, Europe, Canada and the United States. At the end of March, the AKP Unit for Housing at the Graduate School of Design at Harvard co-sponsored a seminar in Paris with the Arab World Institute entitled "Urban Regeneration and the Shaping of Growth." The seminar attracted senior professionals from the public and private sectors in a number of European and Third World countries responsible for the design, development and management of large-scale urban projects. Case studies were presented on Aleppo, Algiers, Barcelona, Istanbul, London, Riyadh, and Shanghai, with a special presentation of the master plan for Makkah.

RONALD B. LEWCOCK and BARBRO M. EK

Center for Advanced Visual Studies

The Center for Advanced Visual Studies, founded in 1967 by Professor Gyorgy 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, with presentations by many CAVS Fellows, address students from virtually all MIT Courses, e.g. "Art and the Environment," Fall '87 and "The Artists Speak", Spring '88. Introductory drawing classes (by Nishan Bichajian) representation of the human figure and basic drawing skills and techniques were topical.

In the Master of Science in Visual Studies Program, headed by Otto Piene, four Environmental Art theses were completed: "Vista Genesis" by Shawn Brixey; "Ovisac Fovea: Toward a Tactual Aesthetic" by Catherine Judge; "Meditative Videos" by Atsushi Ogata; "A Technique for Creating New Visual Phenomena" by Don Ritter. Mr. Brixey presented installations of his light/sound sculptural systems, and Ms. Judge and Mr. Ritter had exhibitions and performances on the MIT Campus and inside CAVS. Mr. Brixey and SMVisS graduate, dancer Laura Knott, performed "Sky Chasm" and other dance-and-sculptural pieces at Documenta 8, the international quintennial exhibition of contemporary art in Kassel, Germany in the summer of 1987.

In July 1987 the Visual Arts Center of Alaska in Anchorage, Alaska, co-produced with CAVS "SKY ART Alaska '87," a series of sky events and installations in Anchorage featuring Otto Piene's and Chris Janney's sky event, "Flying Heartbeat."

An integrated, collaborative CAVS group effort produced concept, execution, and installation of the kinetic light exhibition, "LightsOROT," at the Yeshiva University Museum in New York which commissioned the three year effort with CAVS Fellow and Fine Arts Chairman at Pratt Institute, Mel Alexenberg and Otto Piene as design curators. Other major participants are CAVS Fellows Shawn Brixey, Lowry Burgess, Paul Earls, Elizabeth Goldring, Joe Moss and former Fellows, Harold Tovish and Wen Ying Tsai. The exhibition had its internal opening in December, 1987; its public opening in January 1988. It occupies the entire museum and will be on view through 1988. Its theme is the contemporary, artistic interpretation of traditional articles of religion through recent media of art-and-technology, e.g. inflatables, optics applications, lasers, video, computer.

CAVS is art design consultant to Monacelli Associates, Architects, and The Halvorson Company, Landscape Architects, and the Cambridge Redevelopment Authority toward the creation of a major environmental, kinetic sculpture, "Galaxy," in the Kendall Square area. Execution will begin in late 1988.

In April, 1988, CAVS celebrated its 20th anniversary with exhibitions and events in and around its W11 building. 150 former Fellows and MSVisS alumni were present for a performance, poetry readings and meetings program addressing past and present work and future directions of search and education at the Center culminating with an inflatable sculpture installation above the building, "MIT Red, White, and Blue."

A group of CAVS artists created a new version of "Monocle," a CAVS interactive group sculpture/environment of viewer-orchestrated light and sound in a mirror shell configuration, "Double Monocle," for a large exhibition of art-science-technology, "Images du Futur" in La Cite des Arts et des Nouvelles Technologies de Montreal, Quebec, Canada. Besides "Monocle" participants Lowry Burgess, Paul Earls, Christopher Janney, Joe Moss, Otto Piene, many former CAVS Fellows contributed substantially to the exhibition.

An earlier, combined "Monocle," "Berlin Star" (Otto Piene), "Sound Stair" (Christopher Janney) exhibit at the Boston Museum of Science in the fall of 1987 served as a prelude to the Montreal environment.

Individual artistic projects included Paul Earls' participation (also former Fellows Milton Komisar and Wen Ying Tsai) in "Digital Visions" at the IBM Gallery in New York City, 1988; Dieter Jung's one-man exhibition, predominantly of holograms, at the Paris Art Center, 1988; Otto Piene's participation with sky events in the "Westweek" conference in Los Angeles, California. Both founding director, Gyorgy Kepes, and current director, Otto Piene participated in several international art exhibitions and had several one-man exhibitions internationally.

CAVS Fellows Ellen Sebring and Beth Galston produced "Aviary," a video performance at the MIT Media Lab, with grants from the National Endowment for the Arts, the Massachusetts Council for the Arts and the

MIT Council for the Arts. Elizabeth Goldring and Vin Grabill created "The Inner Eye," a videotape sponsored by the Diabetes Research and Education Foundation. Jose Nuno received an art research grant from the Gulbenkian Foundation; Thorbjorn Lausten from the Danish Government; Attila Czaji from the Government of the People's Republic of Hungary.

Elizabeth Goldring wrote a programmatic essay on CAVS and sky art for Leonardo magazine. The substantial LightsOROT catalog presents essays by Rudolf Arnheim, Mel Alexenberg and Otto Piene. A book on Otto Piene (Galerie Loehrl, Moenchengladbach, F.R. of Germany) includes excerpts from his poems and manifestos. Elizabeth Goldring curated a CAVS exhibition, "Interfaces - Artists and Technology," for the arts festival at the Festival Gallery in Lancaster, Ohio.

OTTO PIENE

Center for Real Estate Development

The Center for Real Estate Development (CRED), founded in 1984, promotes the improvement of the practice of real estate development through education and research into critical issues. CRED's major activities include 1) a 12-month MS in Real Estate Development program for 35 mid-career students; 2) courses that attract more than 100 students from other departments throughout the Institute; 3) research support for MIT faculty and students that generated one report and five working papers this year; 4) professional development courses for industry practitioners. During its fourth year of operation the Center has further strengthened and refined its academic program and increased its research efforts while maintaining its funding base of member companies.

ACADEMIC PROGRAMS

In October 1987, the third CRED class of 34 students, plus two additional joint degree candidates, were awarded their MS degrees in real estate development. The CRED class of 1989 was selected in February 1988 from a well qualified applicant pool that was 25 percent larger than last year's, probably reflecting the increased value of an education in real estate development as the market tightens, as well as efforts to publicize the program. Almost 30 percent of the class are women, a percentage that has remained fairly constant over the past four years. Our desire to promote minority interest in the program bore some fruit as three minorities are members of the incoming class. Two new minority fellowships of \$12,500 each were established by CRED and will be awarded for the first time in the coming year.

Students in the masters program are required to take eight core courses. Most of these were created specifically by MIT faculty for this program. All of them have been substantially revised in an ongoing process. This year new case materials were added to the growing stock, particularly in the finance, politics, and management courses. Computer-based exercises are used, as is interactive video. Two interactive video lessons on negotiation developed by CRED, the Lincoln Institute for Land Policy, and the Harvard Program on Negotiation recently became widely available. Current curriculum development efforts are focused on the creation of materials that integrate different disciplines and professions.

The Center, with the support of the Mayor's Office of Jobs and Community Services and the Minority Developers' Association of Boston, offered a pilot program designed to help minority developers in the Boston area improve their market opportunities and take part in the current expansion in commercial real estate development. The Minority Developers Executive Program (MDEP) enrolled 24 students in a short rigorous course that focused on project selection and management, financial decision making, and marketing of commercial and retail properties. The program, which was taught at Endicott House in two segments, involved almost the entire faculty who teach CRED core courses. All faculty time was contributed pro bono. Inquiries have been received from a number of cities interested in offering a similar program.

The Center continues to sponsor short summer professional development courses to help keep practitioners in the field current with the latest trends. The schedule for 1988 included new courses in property management, marketing residential property, managing growth in the development firm, and deal restructuring, as well as a core of courses that have been given for a number of years.

Next June CRED plans to expand its offerings to the industry by presenting the first session of a new executive education program aimed at CEOs and those of comparable experience. Planning and curriculum development for the program are well under way. The course objectives include the encouragement of lateral thinking, the enhancement of management strengths, and the growth of strategic skills. Marc Louargand, a professor of real estate and corporate finance at the University of Massachusetts, has joined the Center to lead in the planning for this project as well as to engage in research.

RESEARCH

This year research has taken a larger share of CRED's attention and resources. Associate Professor Lawrence Bacow, the Center's first Director of Education, returned from a two-year leave in July to take over for Professor Bernard Frieden as Director of Research. Sandra Lambert has accepted an appointment as a Lecturer to continue her work teaching and developing curriculum and to help with research projects. Over the past year the Center has worked to strengthen its research in the field of finance; in the year ahead we hope to build our work in the areas of design and building technology.

The National Association of Realtors (NAR) has expanded its support for a continuing study of foreign investment in the U.S. Professor Bacow's working paper evaluating foreign investment was based on last year's thesis research on three cities by CRED graduate students supported by NAR. The student research on Washington, DC was also published as a report. Current research will update information on the original cities, add two second-tier cities, and investigate vertical integration by both foreign and domestic real estate companies.

An investigation of the relationships between the phases of the business cycle and returns on direct investment in real estate and on investment in real estate securities has been undertaken by Professor Bacow and Associate Professor Lynne Sagalyn, with support from Citicorp. They are also creating a conceptual framework for analyzing real estate in a recessionary environment and analyzing the changing role of real estate in the business cycle.

Professor William Wheaton completed two studies of U.S. office markets, one concerning vacancy rates and the movement of office rents, and one predicting prospects for the future. Together with Visiting Assistant Professor Denise DiPasquale, he also analyzed the "cost of capital" and rental adjustments in multi-family housing.

The Center also edited and published a series of 20 papers on U.S. housing policy, the result of a major project undertaken by Professor Langley Keyes and Assistant Professor DiPasquale with foundation support from Ford, Robert Wood Johnson, and Fannie Mae, and additional funding from Freddie Mac.

MEMBERSHIP

Most of the founding members of the Center are still enrolled, while 11 companies became members for the first time. This year the categories of membership in the Center were reduced to two, nonprofit and full membership. This change increased the funding from member companies which provides 40 percent of CRED's income. Members again made significant contributions to the academic program through hosting case studies, through presentations as guest lecturers in class and in the weekly "Lunchbox Lecture" series, and by supporting student thesis research in various ways. The Lunchbox Lectures will be funded next year by a generous gift from a member firm, Rose Associates. Participation by members in different aspects of the Center's work increased last year, continuing a trend we value.

Members' meetings were held in the late fall and in early summer. The theme of the December meeting was "Diversification," with 1987 Nobel Laureate Professor Robert Solow giving the keynote speech on the U.S. in a world economy. In June the meeting focused on "Managing for Change." Associate Professor Eleanor Westney of the Sloan School set the theme for the meeting with her talk on "Competitive Management in a Globalizing Industry."

ALUMNI

CRED alumni have organized an association to continue the close bonds which developed among them during their year at the Center. They meet twice a year, a working weekend with participating faculty and business leaders in the spring and a meeting with a more social focus in the fall. Robert Anthonyson, CRED '86, is the 1988 president of the alumni group.

The Center is now preparing for a five-year review, as stipulated by the initial approval granted by the Institute.

JAMES MCKELLAR

Laboratory of Architecture and Planning

The School of Architecture and Planning's research showed considerable vitality and growth in the past year. Important issues were brought to national attention as a result of our research. For example, completed research about national housing policy, directed by Department of Urban Studies and Planning Professors Keyes and DiPasquale, provided the background for the National Housing Task Force created by the U.S. Senate. As another example, symposia by School researchers about real property portfolio management, convened by the MIT Industrial Liaison Program and the U.S. General Services Administration, introduced this new management discipline to a broad audience of private and public managers. The long-term research agreement reached between CRED and Citicorp; the multiple company support for housing materials research; and the ongoing long-term research program with the Shimizu Corporation are very positive models of School-industry collaboration.

Research projects based in the Laboratory of Architecture and Planning (LAP) are directed by LAP faculty and research staff, and often involve outside professionals and organizations as well as students. Funding for the LAP's broad range of projects comes from government on the national, state, and local levels; from foundations, industry, and individuals. The international relevance of the work conducted through the LAP is indicated by the support of international agencies as well as industry and foundations outside the US.

Many activities of the School of Architecture and Planning are organized as special interest programs; the LAP serves as the administrative base for all of the sponsored research and many of the educational workshops conducted within these programs. Among the programs are: The Center for Real Estate Development (CRED), the Professional Practice Program for Housing and Human Settlements, the East Asian Architecture and Planning Program (EAP), the Aga Khan Program for Islamic Architecture (AKP), the Special Program for Urban and Regional Studies (SPURS), the Computer Resource Laboratory (CRL), and the Program for Neighborhood and Regional Change.

In addition, the LAP has strong connections with other centers of research at MIT. The LAP actively collaborates with colleagues in the Sloan School of Management, the MIT Joint Program for Energy Efficient Buildings and Systems, the Media Laboratory, and the Center for Construction Research and Education, among others. The LAP also is involved in research and special educational efforts on a collaborative basis with institutions in East Asia, the Middle East and Latin America.

The School's base for research was strengthened considerably this past year. CRED established a research agenda with strong faculty commitment; the Architecture Department's recently enlarged building technology group also developed a research agenda and targeted development strategy; and several cohesive research clusters have emerged with long-term faculty commitment to an agenda for research. Illustrative of targeted topical areas are: housing, real property portfolio management, design process, public policy negotiation, job generation, and the geographically focused East Asian Architecture and Planning Program. New research staff have been recruited to broaden faculty resources for many of these activities. The LAP has continued to play an incubating and supportive role for research development throughout the School. The coming year will be a time to review, restructure, and strengthen the role and strategy of the LAP.

CURRENT RESEARCH

Professor Lawrence Bacow and James McKellar (Center for Real Estate Development) will undertake a study of the performance of real estate in a recessionary environment sponsored by Citicorp Real Estate, Inc. The project will entail preparation of research papers that will encompass numerous subtopics.

Professor Ranko Bon (Department of Architecture) and Michael Joroff (Laboratory of Architecture and Planning) continue as co-Principal Investigators for a project to develop a theory and basic methodologies for building portfolio management. This research focuses on how private companies and institutions comprehensively manage large numbers of properties and buildings. A published report "Managing Corporate Real Estate Assets: A Survey of U.S. Real Estate Executives" resulted as part of the work funded by the Shimizu Construction Company.

Professor Philip Clay (Department of Urban Studies and Planning) has received a grant from the Ford Foundation to develop case studies about the community housing sector primarily addressing the question of what the barriers are to a more effective role on the part of the community-based sector in housing development. The research is divided into three segments consisting of case documentation, analysis of the housing development process and policy analysis.

Lois Craig (Dean's Office, School of Architecture and Planning) continued to serve as Principal Investigator of a National Endowment of the Arts supported program to develop a visual collection describing the Boston suburbs.

Professor Eric Dluhosch (Department of Architecture) completed work on a computer-based educational package designed for the International Masonry Institute. The resulting product, "Masonry Compute", combines an existing data base with a videodisc component and drawing module that provides a tool for designing with masonry. The product has met with success and was the basis of a symposium held at MIT this past spring.

Professor Bernard Frieden (Department of Urban Studies and Planning) and Michael Joroff were co-Principal Investigators for a U.S.-Japan comparative study of public and private interaction in real estate development. The project was funded by the Mori Building Company.

Professors Lorna Gibson (Department of Civil Engineering), Leon Glicksman (School of Architecture), and Research Associate John Crowley (Laboratory of Architecture and Planning) have developed a consortium project to evaluate the requirements for materials in housing construction and to develop new materials for use in housing. Members of the consortium to date are Weyerhaeuser, US Gypsum, Mobay Chemical and possibly General Electric.

Professor Leon Glicksman (Department of Architecture) has received an award from the Environmental Protection Agency to address the means to achieve equivalent or improved energy efficiency in foam insulations which contain environmentally acceptable blowing agents.

Professor Glicksman has been funded by Mobay Corporation to measure the permeability to air components of several foam samples produced at Mobay Chemical Company. The goal of the project is to relate aging to different polymer systems to be used in foam insulation.

Professor Glicksman also is continuing on a renewal project sponsored by Martin Marietta/DOE to address the means to achieve equivalent or improved energy efficiency in foam insulations which contain environmentally acceptable blowing agents.

Professor Glicksman and Research Consultant George Clark (Laboratory of Architecture and Planning) continue to supervise the development of the lighting research and education laboratory. This project is supported by GTE Sylvania.

Professor Nabeel Hamdi (Department of Architecture) and Research Associate Reinhard Goethert (Department of Architecture) completed their work for the Ministry of Housing in Sri Lanka, concentrating on housing and construction policy and strategy.

Professor Bennett Harrison (Department of Urban Studies and Planning) recently received funding from the Ford Foundation to investigate the structure of earnings changed between metropolitan and non-metropolitan areas over time and how this differed by region. Also what factors, both macroeconomic and local, are driving these changes.

Deborah Hoover, a Research Affiliate (Laboratory of Architecture and Planning) continues her research on cultural policy in Gambia. This project is funded through private individuals and foundations as well as support from the Dean's Office (School of Architecture and Planning) and Dr. Jerome Wiesner's office at MIT.

Professor Langley Keyes (Department of Urban Studies and Planning) has been supported by the Ford Foundation, Fannie Mae, and the Robert Wood Johnson Foundation for housing policy research on issues critical to an evaluation of national housing policy with regard to housing affordability, availability, and quality for people of all incomes. The resulting papers will set current practice in the context of past efforts and policy alternatives in the framework of present institutional realities. This volume of papers which will lay out the critical issues, pull together the current thinking and data, and consider a variety of policy options, will be an important document for future discussion.

Professor Donald Schon (Department of Urban Studies and Planning) sponsored by the National Endowment for the Arts, devised a flexible notation system which describes the history of a process move by move and analyzes it from different perspectives. The system is meant to be used as a research-aid in diverse design-research studies and as an educational tool to help demystify intuition and provide insight and feedback.

Professor Schon also has recently received an award from the Ford Foundation to document "best practice" in social investment and to provide Foundation staff with an opportunity to think together about how these instances of "best practice" might inform their daily work.

Professors Schon and Louis Bucciarelli (School of Engineering) continued for a second year as co-Principal Investigators on a grant from the National Science Foundation to support their project, "Describing and Modeling Designing and Design Knowledge in Architecture and Engineering". This project continues to explore the applications of the constraint model; observations, simulation and exploration of the use of a constraint manager in collective designing; using design exercises to explore the development of leading ideas and reviewing computer environments for designers.

Professor Lawrence Susskind (Department of Urban Studies and Planning) is the recipient of a research agreement with American Energy Assurance Council (Apache Corporation) for support of a Crisis Simulation Game to demonstrate to the participants that energy policy decisions made during a crisis must compromise vital interests of various constituencies in unpredictable ways.

Professor Susskind, sponsored by the Department of Labor, is working to produce a videotape to be used in a regional workshop as a means of introducing labor and management personnel involved in collective bargaining to the elements of 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

A Japan-US Urban Development Workshop in Tokyo, sponsored by Japanese corporations, presented a two-day workshop to define a long-term, US-Japan comparative research program.

The National Institute of Building Sciences Conference, co-sponsored by the Laboratory of Architecture and Planning, dealt with foreign involvement in US markets for real estate housing and construction.

The Industrial Liaison Program Symposium addressed strategies for the effective management of large portfolios of buildings and land by organizations not primarily involved in real estate.

The General Services Administration Symposium involved a discussion on the importance of shaping and managing organizations' real property portfolio to satisfy business plans and objectives.

The Beijing Studio focused on large-scale design opportunities in areas of Beijing. The studio included regular lectures on Chinese architecture, history and city development, as well as a guided study tour to several cities in China.

The Laboratory of Architecture and Planning conducted a workshop with the Japan Construction Training Center (Zenkoku Kensetsu Kenshu Center) for selected Japanese people on changes, redevelopment and social problems in the modern city.

The Seoul Conference, the third international conference of the MIT East Asian Architecture and Planning Program, was a study on the long-term impacts of hosting the Olympics upon a host city. It provided a forum for the sharing of the experiences of other Olympic host cities in the Pacific Basin.

The Seoul Studio brought together students from North America, Korea and other East Asian countries to work together on exploring current architectural and urban design issues in Korea's capital city.

The Kawasaki Advanced Information City Workshop will explore the concepts, development strategies and social opportunities of cities as they emerge in the 21st century, increasingly heralded as the age of the advanced information society. It will bring together participants from many countries, including Japan and other Asian countries, plus North America, Australia and Europe.

The Boston Redevelopment Authority and the Laboratory of Architecture and Planning held an economic urban round-table to discuss the future of major cities. Forty invited U.S. experts participated in this symposium.

Biennial Shelter Workshop 1988 was a two-week action-oriented workshop presented by experts in community based planning, or microplanning. Participants were people from developing countries including Africa, Asia, South America and Europe, as well as the U.S. The sessions examined building skills, managing land, promoting public-private partnerships, strengthening local government support, design evaluation and implementation of modern technologies.

The LAP continues as one of the sponsors of Open House International, an international journal of housing, co-edited by Professor Nabeel Hamdi of MIT's Department of Architecture.

STAFF

During fiscal 88 the LAP hosted three new Visiting Research Scholars. Osamu Koide, an Associate Professor for the Department of Urban Engineering, University of Tokyo; Jin Kim, an Associate Professor from Seoul National University; and Shuzo Nishioka, from the National Institute for Environmental Studies in Japan.

Three new persons joined the LAP: Susan Glenn, a new support-staff employee; Research Associate John Crowley; and Research Affiliate, Mark Weiss. In addition, the LAP is the base for the research staff of the Center for Real Estate Development, Mary Lou Boutwell, Sandra Lambert and Marc Louargand.

MICHAEL L. JOROFF

Media Arts and Sciences Section

This year marks the Media Arts and Sciences (MA&S) Section's first year as a distinct academic entity within the School of Architecture and Planning. Professor Stephen A. Benton serves as the first Head of the Section, and reports to Dean John de Monchaux. Prior to July of 1987, the curriculum offered to students in the Media Laboratory was administered through the Department of Architecture. Although the Section's degree programs continue to be affiliated with the Department of Architecture, they reflect an increasing commitment to the development of Media Arts and Sciences as a separate academic discipline.

The Section's academic infrastructure is built on three faculty committees concerned with the supervision and integrity of the MA&S academic programs. The Committee on Graduate Students, led by Professor Benton, monitors the progress made by MA&S students in the completion of their degree programs. The Committee on Degree Requirements concentrates its efforts on the refinement of the degree requirements, their articulation and implementation. Finally, an ad hoc Committee on the Pro-Seminar, led by Professor Seymour Papert, has brought the various disciplines within the program together in a Pro-Seminar that is now a requirement for all Doctoral candidates within the MA&S Section.

EDUCATION

The admission of 22 new graduate degree candidates last September brings the number of graduate students currently enrolled in the MA&S Section to 57. The MA&S Master's program has 37 registered candidates; its Doctoral program has 20. The areas of specialization offered to MA&S students include: electronic media, computer graphics, learning and epistemology, music and cognition, image and signal processing, computers and design, vision science, and spatial imaging. A total of 44 subjects of instruction were offered by the Section this year. Students in the MA&S Section also serve as Research Assistants with Media Laboratory research projects. The mix of previously separate academic interests within the MA&S degree program and the research environment of the Media Laboratory makes a Media Arts & Sciences education a unique interdisciplinary experience.

This June the Section awarded its first three Doctoral degrees: one with a specialization in Electronic Publishing and two in Learning and Epistemology. The MA&S Section's Master's course was successfully completed by nine students last year with specializations in holography, electronic publishing, film and video, computer generated animation, and computer simulation of animal behavior.

Although the Section does not offer an undergraduate degree concentration, the number of undergraduate subject offerings increased this year to 18. The Section has begun planning an undergraduate curriculum for implementation in the future. In addition, through the UROP program, 64 undergraduates were able to participate in Media Laboratory research programs alongside MA&S graduate students.

FACULTY AND STAFF

Of the Section's 13 faculty members, two have joint appointments with other Departments of the Institute. Three others, while appointed in other Departments, find their academic homes within the Media Arts and Sciences Section. In January of this year, we began a worldwide search to fill five faculty positions. This search continues. To supplement our teaching and research efforts, the Section employs an academic staff of twelve. This year's appointments and promotions are listed below:

Professor Muriel R. Cooper was promoted this year to Professor of Visual Studies, recognizing the leadership she has brought to the Visible Language Workshop in the field of computer interfaces and graphics.

Associate Professor Alexander Pentland was named to the NEC Computers and Communications Career Development Chair for two years, in recognition of his work in communications, computers and design.

Assistant Professor Van Jay Wedeen has joined the faculty, jointly and principally with Whitaker College, and is teaching and pursuing research in medical imaging.

Assistant Professor Glorianna Davenport has joined the faculty, jointly with the Department of Architecture, after serving for several years as a Lecturer in Film and Video.

Linda G. Peterson, formerly of the office of the Dean of the Graduate School, has joined the Section as Administrator of its Degree Programs.

STEPHEN A. BENTON
Section Head

Media Laboratory

The Media Laboratory (Media Lab) concludes its fifth year of existence and its third year in the Wiesner Building with this report. The year marks another milestone in the Lab's rapidly increasing research volume, which reached \$5.4 million, an increase of better than 50 percent over last year. Growth in research volume is anticipated to continue at strong rates for the next few years and to then level out at about \$10 million per year in 1992 dollars.

The character of funding remains largely industrial, with 74 percent of the Media Lab's research volume sponsored by US, European, and Japanese individual companies or consortia of companies. This is in comparison with the Institute's on-campus average of 13 percent industrial sponsorship. National Science Foundation (NSF) sponsorship increased dramatically, from a total of \$77,000 in FY '87 to \$938,000 in FY '88 in four separate projects. A broader balance of sponsorship is anticipated for next year, with several large proposals in progress to US Government agencies including NSF, Defense Advanced Research Projects Agency (DARPA), and the Department of Education.

This research supported a total of 62 full-time research assistants from the Media Arts and Sciences M.S. program (32), the Media Technology Ph.D. Program (18) and from other departments including Electrical Engineering and Computer Sciences (13) and Mechanical Engineering (2).

The most prominent event of the year was the publication of Stewart Brand's book, *THE MEDIA LAB: Inventing the Future at MIT*, published by Viking Penguin Incorporated, in August 1987, and translated into Japanese by Fukutake Publishing Company in April 1988. With 75,000 copies in English and 25,000 in Japanese, the book has generated a flood of interest in the Laboratory and literally hundreds of press reports and articles. Over 3,000 people have visited the Media Lab this year, as part of industrial, academic or professional groups. While the book is over popularized in tone and not all inclusive, it captures a feeling and enthusiasm, of which we are proud. One result is that the management of communications and sponsor relations has assumed considerable importance.

Media Laboratory

Research Groups

Advanced Television Research Program

Computer Graphics & Animation

Electronic Publishing

Learning & Epistemology

Film & Video

Human Interface

Movies of the Future Program

Music & Cognition

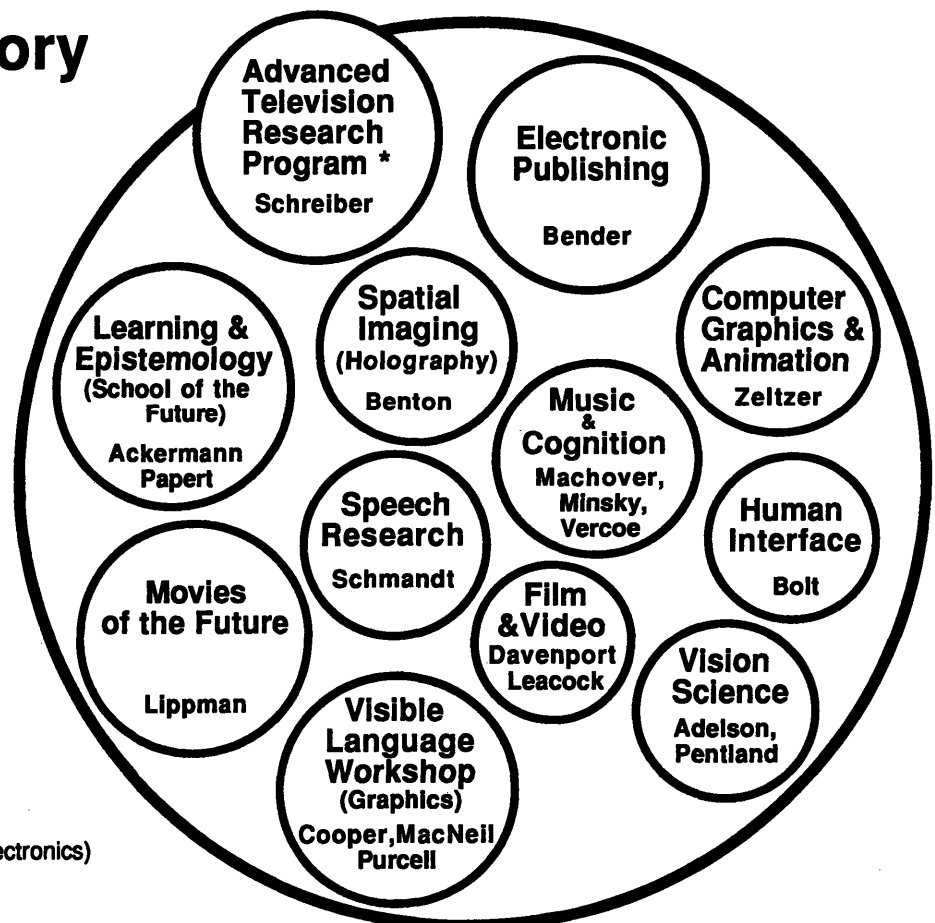
Spatial Imaging

Speech Research

Visible Language Workshop

Vision Science

(*jointly with Research Laboratory for Electronics)



This year was also the first full year of implementation of the Media Lab's \$10 million accord with Nihon University to help develop a new research institute in Japan, the International Advanced Research and Development Institute (IARDI). Professor Tomoyuki Sugiyama has been resident at the Media Lab for the year as the first of the long-term program visitors conducting research and studying the operation of the Laboratory. Professor Nicholas P. Negroponte has been in Japan five times during the year for IARDI planning and strategy meetings. The first joint International symposium was held in Japan on December 1 and 2, 1987 and included participation by Professor Negroponte, Professor Seyour A. Papert, and Professor Alex P. Pentland from MIT. Also during the year other faculty and staff including Mr. Andrew B. Lippman, Professor Muriel R. Cooper, Professor Barry L. Vercoe, and Professor David L. Zeltzer visited Nihon University to present seminars. Two major teams and five smaller groups from Nihon University and IARDI visited the Media Lab to acquaint themselves with the research programs of the Laboratory. The construction of the IARDI Laboratory in Japan is anticipated to start in April 1990.

RESEARCH

The balance of this year's statement consists of reports from projects, versus research groups, as we have listed them in the past. In the research activity of this Laboratory, one may discern a primary division between a broad spectrum of applications and the technologies that serve these applications. Media Technology, in its role of mediation between the user and the user's information environment leads us to the concept of the human interface. The theory and techniques of signal processing provide a methodological infrastructure to many of the projects in the Laboratory. The applications illustrate the broad spectrum of human affairs touched by this new interdisciplinary field. The following sections are sequenced as HUMAN INTERFACE, SIGNAL PROCESSING, MEDIA TECHNOLOGY and APPLICATIONS OF MEDIA TECHNOLOGY.

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.

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 peoples' body positions as they point and move about in the work environment; (2) "Lip reading" e.g., augmenting auditory speech recognition with visual cues; (3) Person identification, principally by recognition using the relative size and position of facial features and body parts.

Micro-Movies (Mr. Walter R. Bender/Mr. 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.

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 both 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 user's hand. This interface for computer graphics makes it possible for users to directly manipulate virtual objects in these simulated environments.

Tactile Simulation/Forced Feed Back Lever (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.

Alcove Holograms (Professor Stephen A. Benton)

Recent research in this area has led to the invention of a white-light viewable version of the alcove projected-image hologram, which permits full-color "walk-around" images to be produced.

Font Scaling (Mr. 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 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.

Back Seat Driver (Mr. 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 (Mr. 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.

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 eight 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.

Paperback Movies (Mr. Andrew B. Lippman)

A three-year, multi-sponsored venture is being undertaken 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 Movies 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.

Electronic Holography (Professor Stephen A. Benton)

Research in electronic holography is leading toward what we expect to be the world's first demonstration of holographic video at practical bandwidths.

Low Level Vision Mechanisms in Humans and Machines (Professor Edward H. Adelson)

A number of techniques are being used to study the basic mechanisms underlying human and machine vision. Psycho-physical experiments are used to test models of how humans process stationary and moving patterns. Computational studies are used to determine the power and limitations of various image processing algorithms. One topic of special interest is the analysis of visual motion; we are developing computational algorithms that have some formal similarities to the computations underlying human motion perception.

Pyramid Image Representations (Professor Edward H. Adelson)

A pyramid image transform is a multi-resolution image representation. The image is broken down into a set of band-passed subimages, where each subimage contains information at a particular scale. Pyramids are useful for a variety of tasks in image processing, machine vision, computer graphics, and image data compression. Much of our current effort involves pyramids based on quadrature mirror filters; these show great potential for the efficient storage and transmission of images.

MIT-RC (Receiver Compatible) Project (Professor William F. Schreiber)

The MIT-RC project is a one channel (6-MHz) receiver compatible EDTV system which has been developed as an outcome of the Advanced Television Research Program (ATRP) and has led to the concept Open Architecture TV Receiver described overleaf. It features improved resolution on special receivers, satisfactory reception on existing receivers, freedom from NTSC cross-effects and in one form, digital audio.

MIT-CC (Channel Compatible) Project (Professor William F. Schreiber)

The MIT-CC project is a one channel (6-MHz) noncompatible 6MHz system which like the MIT-RC project above has been developed as an outcome of the ATRP program. It features both resolution and digital/audio capabilities comparable to Japanese HDTV transmission systems, but on special receivers only.

Depth From Focus (Mr. 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 range finders. 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 range finders) 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.

Adaptive Color Coding (Mr. 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 frequencies that have been used to bias the statistical analysis of 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.

MEDIA TECHNOLOGY

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 multi-faceted subject in projects which link audio, video and all the modalities of input/output are illustrated in the following projects.

Self-Disclosing Television (Mr. Walter R. Bender/Mr. 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.

Hard News (Mr. Walter R. Bender)

An investigation is being undertaken 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.

Unrecordable Video (Mr. 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.

Interactive Cinematics (Professor Glorianna Davenport)

The context for this project is the development of new cinematic technologies and the evolution of new forms. Currently, the thrust is the development of a system, in which interactive video sequences are linked with a variety of knowledge and data bases about the subject matter of the movie. A recent advance has resulted in the ability to run video-graphics, audio, and data on a single screen display. A current cinematic case study is "City in Transition: New Orleans, 1983-86," which explores the process and impact of the rapid development of this city's downtown riverfront area.

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.

Open Architecture TV (Professor William F. Schreiber)

This program has the goal of developing the scientific and technological basis for the improvement of TV systems. Progress has been made in developing a computer-based simulation system for the complete TV process from object to image. Motion-compensation methods have been developed for image enhancement, coding, and frame-rate conversion. The MIT-RC and the MIT-CC projects (see above) have both contributed significantly to the concept of the Open Architecture TV.

Personalized Newspaper (Mr. 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.

TV Audience Research Project (Dr. W. Russell Neuman)

This project is one of a number, whose goal is to test viewer reaction to improved TV systems through the use of a specially designated research facility in a shopping mall in Danvers, Mass. Investigations have been carried out on a variety of TV viewing subjects, including a pioneering study of the comparative reaction to HDTV (High Definition TV) and NTSC; and viewer preference with respect to aspect ratio, image resolution, and screen size.

Tools Linking Computers and Telephones (Mr. Christopher M. Schmandt)

This project studies tools to enhance the link between computers and telephones in a context of voice communication.

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), medical imaging, transportation, and the performance arts, illustrates this variety.

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/Mr. 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.

Graphic/Photographic Imaging for Medical Simulation (Mr. Andrew B. Lippman)

Exploration of imaging techniques for medical simulation and training. Specifically, the program addresses the merging of available imaging systems with computer generated data bases to provide a joint and simultaneous three-dimensional moving image system where some of the data is provided by the imaging system and the rest from the data base. An arthroscope and a model of a human anatomy are the test subjects, and the view through the arthroscope will be merged with a computer model of the knee to allow alternative views, additional information presentation, and simulation of situations that cannot be simulated with a mechanical anatomic replica.

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 Design Layout System (Professor Muriel R. Cooper/Mr. Ronald L. MacNeil)

This project is an integrated graphic design system linking information gathering, layout and design in a high performance graphics workstation.

DAIS (Do As I Sketch) (Professor Muriel R. Cooper/Mr. Ronald L. MacNeil)

"Do As I Sketch" uses visual design knowledge to produce page layouts for one page photo essays. This knowledge is about visual grouping of layout elements based on proximity. The DAIS user specifies the overall spatial arrangement of the page by means of a freehand sketch. DAIS uses its visual design knowledge to place layout elements so that they form groups that correspond to elements of the sketch. It is one of a number of projects investigating the intersection of design knowledge with graphic design.

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 now expect to have available.

Hyperinstruments (Professor Tod Machover)

Hyperinstruments is a project which mixes new ideas of musical virtuosity with intelligent machine understanding and music structure generation. Such instruments were used for Machover's VALIS opera, which premiered at the Paris Pompidou Center in December 1987.

The Synthetic Performer (Professor Barry Vercoe)

Real-Time Computation in Contexts of Skilled Human Performance is the theme. Development of synthetic human performance by putting computer systems in situations of highly sensitive human interaction is the goal. A synthetic musical instrument will be introduced into a close-knit performing ensemble without disturbing its normal musical behavior. The project involves tracking of human performers (fingering and sound); extraction of tempo, loudness, and stylistic information; then construction of control processes to manage flexible real-time audio processing.

The Artificial Acoustic Ambience (Professor Barry Vercoe)

This is 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.

Synthetic Holography for Computer Aided Design (Professor Stephen A. Benton)

Synthetic holography research has produced what may become the first practical method for full-color holography. The method is based on a novel chemical technique for controlling the swelling of holographic recording layers, and computer graphic compensation of the color mis-registration that has accompanied previous attempts at full-color holography.

Holographic Overlays for Air Traffic Control (Professor Stephen A. Benton)

This is a research project with the goal of producing holographic overlays for proposed air traffic control displays, providing a 3-D visual matrix of allowed traffic spaces through which aircraft would be guided.

Holograms for Medical Imaging (Professor Stephen A. Benton)

The development of synthetic holograms to enhance visualization in a variety of medical applications using data (both CAT scans and MNR data) obtained from medical sources.

Computer Supported Exploratory Design (Professor Alex Pentland)

A starting project that will be concerned with the development of software tools to support the initial, exploratory stages of design.

Programming by Example (Mr. Henry A. Lieberman)

The principal thrust of "Programming by Example" is the development of a knowledge acquisition method for graphic design applications. It is one of several related projects at the intersection of artificial intelligence and computer graphics. These have the overall aim of helping programmers to better visualize the operation of software for symbolic programming applications using color, animated typography and three dimensional imagery.

PERSONNEL

Professor Nicholas P. Negroponte continued as Director of the Media Laboratory with a major focus on strengthening sponsorship, research programs and staffing of the Laboratory, in concert with the Media Arts and Sciences Section which is closely coupled to the Laboratory and is reported separately this year in this report for the first time. Mr. Andrew B. Lippman completed his first year as Associate Director and Mr. Robert P. Greene continued as Assistant Director for Administration and Finance at the Laboratory.

Professor Patrick A. Purcell, who has been a Visiting Associate Professor of Computer Graphics at MIT since 1982, took on additional Media Laboratory responsibilities in March 1988, when he was named Director of Communications and Sponsor Relations. His previous experience at the Royal College of Art in the U.K. in research and sponsor relations and his academic perspective have added new dimensions to this critical area. Mr. Timothy P. Browne continues as Associate Director of Communications and Sponsor Relations with a special focus on Japanese sponsors, programs, and research affiliates.

Dr. W. Russell Neuman was appointed Principal Research Associate and Director of the TV Audience Research Facility at the Liberty Tree Mall in Danvers, Mass. and moved his research programs from the Political Science Department to the Media Lab at the end of the year. Ms. H. Lauren Zachmann was named Staff Administrator in Finance and Administration in January.

Dr. Sylvia Weir, a Principal Research Scientist with the Learning and Epistemology Group retired in January. Ms. Judith Whipple, Administrative Manager of the Music and Cognition Group, who had managed the Concert Series for the last five years, left at the end of the year. Other staff departures during the year included Ms. Vanessa Boris and Mr. Jason Kinchen.

New additions to the Laboratory staff during the year included Mr. Anh V. Ho and Ms. Julie Rohwein as System Programmers; Mr. Robert Murray as Computer Hardware Coordinator; Ms. Victoria Bippart as Equipment Room Coordinator; Ms. Julie L. Walker and Mr. Stanley Strickland as Research Associates; Dr. David A. Levitt and Mr. Henry A. Lieberman as Research Scientists; Mr. John Berlow as Technical Assistant; Mr. Pascal Chesnais as Research Specialist; and Ms. Jacqueline Karaaslanian as Research Administrator.

MEDIA LABORATORY SPONSORS

The following list indicates the wide pattern of research sponsorship (from both the public and private sectors) that supports the work of the Media Laboratory. The geographic spread is also wide. The industries represented are disparate: telecommunications and broadcasting, print and publishing, computers and electronics. Association with the research in the Laboratory takes several forms, including discretionary and directed research as well as several forms of endowment.

Endowment

NEC Corporation
Fukutake Publishing Company
International Advanced Research
& Development Institute

Directed Research

Advanced Environmental
Research Group (AERG)
Ampex Corporation
Apple Computer, Incorporated
Capital Cities/American
Broadcasting Company (ABC)
Columbia Pictures Industries, Inc.
Control Data Corporation
Defense Advanced Research
Projects Agency (DARPA)
Dr. -Ing Rudolph Hell GMBH
General Motors Corporation
Home Box Office (HBO)
Hell Graphic Systems
Hughes Aircraft Company
Institute of Computer Literacy (ICL)
International Business Machines
Interlego A/S
Eastman Kodak Company
John D. and Catherine T. MacArthur
Foundation
Massachusetts Council on the
Arts and Humanities
National Broadcasting Company(NBC)
National Endowment
for the Arts (NEA)
National Science Foundation (NSF)
Nippon Hoso Kyokai (NHK)
Nippon Telegraph & Telephone (NTT)
NYNEX Corporation
Paramount Pictures Corporation
Public Broadcasting System (PBS)
Polaroid Corporation
RCA Corporation
Systems Development Foundation
Tektronix, Incorporated
US West Advanced Technologies, Inc.
Warner Brothers, Incorporated
Zenith Electronics Corporation

Discretionary Research

Activision, Inc.
American Bank Note
Holographics, Inc.
Apple Computer, Incorporated
Control Data Corporation
Bell Northern Research, Ltd.
Fujitsu Laboratories, Ltd.
Ann & Gordon Getty Foundation
Hitachi, Ltd.
Hughes Aircraft Company
Mattel, Inc.
The MITRE Corporation
Olivetti Advanced
Technology Center, Inc.
Online Computer
Library Center (OCLC)
Polaroid Corporation
Sanyo Electric Company, Ltd.
US West Advanced
Technologies, Inc.

Hardware Grants

Apple Computer, Incorporated
Asahi Broadcasting Corporation
Compugraphic Corporation
Digital Equipment Corporation (DEC)
Gould Electronics
Hewlett-Packard Company
Intel Corporation
International Business Machines
MICOM/Interlan, Inc.
NEC Corporation
Nippon Gakki Company, Ltd.(Yamaha)
Photo Electronics Corporation
Polaroid Corporation
Sanyo Electric Incorporated
Sony Industrial Products
Sun Microsystems
Symbolics, Inc.
Wang Laboratories Incorporated

Building Grants

Adams-Russell Company, Incorporated
American Broadcasting Company (ABC)
Apple Computer, Incorporated
Asahi Broadcasting Corporation
Asahi Optical Company, Ltd.
Asahi Shimbun Publishing Company
Bolt Beranek & Newman, Incorporated
BOSE Corporation
The Boston Globe
Columbia Broadcasting Systems (CBS)
Columbia Pictures Industries, Inc.
Computervision Corporation
Digital Equipment Corporation (DEC)
Dow Jones & Company, Incorporated
Eastman Kodak Company
Embassy Television
The Faxon Company
Fujitsu Laboratories, Ltd.
Hewlett-Packard Company
Hitachi, Ltd.
LaserColor Laboratories
M/A-Com, Incorporated
Matsushita Electric Industrial Company
MCA, Incorporated
The Mead Corporation
Mitsubishi Electric Corporation
NEC Corporation
Photo Electronics Corporation
Pioneer Electronic Corporation
RCA Corporation
R.R. Donnelley & Sons Company
Schlumberger
Scientific-Atlanta, Incorporated
Scott Fetzer Company
Sony Corporation
TIME, Incorporated
The Times Mirror Foundation
TRE Corporation
Wang Laboratories, Incorporated
Warner Communications, Incorporated
The Washington Post Company

NICHOLAS P. NEGROPONTE

SCHOOL OF ENGINEERING

The teaching and research activities of the School of Engineering take place within a structure of eight academic departments, ten centers and laboratories which report to the Dean of Engineering, a number of centers which report to the Provost or Vice President for Research, and a large number of entities organized within the departments. This section of Reports to the President collects reports on those activities within the eight departments and the laboratories and centers which report to the Dean of Engineering. It also contains brief reports on some few activities and programs managed directly by the Office of the Dean of Engineering.

Of these activities, special note should be taken of the initiation of the Leaders for Manufacturing program, directed by Professors Kent Bowen of the Department of Materials Science and Engineering, and Thomas Magnanti of the MIT School of Management. A brief summary will be found below.

Undergraduate enrollment in the School as a whole declined by 145 this year from last, with a substantial and welcome decrease in Electrical Engineering and Computer Science so that this hard-pressed department's 1987 sophomore class was close to the goal of 270. Graduate enrollment also decreased by 77.

The School welcomed 11 new faculty this year, of which five are women. With 15 departures, the School's faculty declined by 4. These reductions in student enrollment and in number of faculty are consistent with the School's desire to reduce the stress on its resources, and improve the quality of life for students, faculty and staff.

Undergraduate Education

The School continued this year to examine possibilities for improvement of the educational experience of its undergraduates, and so pursued several initiatives started in prior years. The latter include regular student-conducted reviews of subjects, Contexts Subjects, and the Faculty Instructional Resource Program.

Enhanced subject reviews have now been conducted three successive semesters, and the results have been published by the CEG (Course Evaluation Guide) and discussed in summary form in Engineering Council, with special emphasis on the student's workload for individual subjects, and on quality of teaching. We have found that there are subjects, small in number but in some cases large in attendance, which routinely require far more than the normal time from students. Actions have been agreed upon in Engineering Council, either to reduce the excessive workloads or to raise the credit allowance for these subjects.

Two Context Subjects were offered in the Spring semester. While the enrollments were modest, the subjects were judged successful by the participants, and provide a basis for enhanced offerings in the coming academic year, when some five subjects will be available.

The Faculty Instructional Resource Program provided a forum for discussion of teaching techniques and the environment for teaching in the School. Its meetings were well attended by new faculty, who amongst other things expressed a strong desire for more information about pedagogical techniques. The program will be expanded to provide such in the coming year, and will also sponsor a series of Master Classes conducted by teachers of recognized virtuosity.

A working Group on the Teaching of Design continued to address means for providing an environment in the School which is more conducive to developing student's design talents.

This year a Science and Engineering Working Group was formed in collaboration with the School of Science, to address those issues in undergraduate education which lie at the interface between Science and Engineering. Chaired by Professors David Wormley of Mechanical Engineering and Robert Silbey of Chemistry, the Group has met intensively during the spring, will continue in the summer and will offer its recommendations in the fall.

During the fall semester of 1987, all engineering departments conducted reviews of their undergraduate programs, addressing their overall structure and how they support realization of the School's objectives for engineering undergraduate education. Some of the more general findings are: that several departments believe four years is too short for a fully professional education, that the bachelors degree must be regarded as a first step only in the educational process for engineers; that there is general support for an Institute Requirement in Biology; that there is strong support for Context Subjects, although not at the expense of engineering subjects, and in some cases the preference is for their incorporation into engineering subjects.

Engineering Internship Program

For the summer of 1988, 59 sophomores have been placed in the Engineering Internship Program, making the total enrollment 139. There are 34 participating companies.

Mr. John R. Martuccelli, the founding Director of the Program, retired on June 30, 1988. Mr. William H. Ramsey has replaced him as director of the EIP and has the additional responsibility of Coordinator of the MITES Program.

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 twelve faculty hires, five were women, bringing the total number of women faculty in the School to twenty.

Minority Introduction to Engineering and Science

In the summer of 1988, 49 high school juniors will attend the MITES program, which introduces them to college level mathematics, physics, humanities, design and computer science, and to the MIT atmosphere. They became acquainted with MIT faculty, and with each other.

This year the Program will be directed by Professor Douglas Carmichael, and coordinated by Mr. William Ramsey.

GERALD L. WILSON
JACK L. KERREBROCK

Department of Aeronautics and Astronautics

The pattern of Departmental activities during the past year has tended towards a well-established pattern. Excluding exceptional events, the Department appears to change slowly - a few more faculty then a few less now. The sophomores arrive and the seniors graduate and leave. The exceptional event this year is the tragic loss of Professor J.F. Louis. He was in Nashville attending the 26th Annual Symposium on Engineering Aspects of MHD. He was killed in an automobile accident while returning to his hotel from a field inspection of an MHD generator at the University of Tennessee Space Institute. We will miss him and his wisdom in our deliberations. We shall also miss Professor Emmett Witmer's wisdom in Department deliberations. Emmett retired after more than a quarter century as a faculty member. His outstanding teaching ability and his popularity with the students, not to mention his ten-year term as Chairman of the Department Undergraduate Committee, have left a mark on the Department that will remain visible for a long time to come. Professor Witmer's retirement has left us in need of a Chairman of the Department Undergraduate Committee; Professor Winston Markey has agreed to assume this responsibility. True to his style, Emmett has spent considerable effort in helping Winston to become familiar with the position. After a decade of leadership, Professor James McCune has stepped down as Chairman of the Department Doctoral Committee in order to spend more time on research. Professor Steve Hall has accepted an assignment to this important position. The Dean of Engineering has announced that Professor Earll M. Murman will be the new Director of Project Athena. We hope that Earll will have the time to continue to take part in Department activities.

Professors Laurence R. Young and Edward F. Crawley have been away on Sabbatical leave. Professor Leon Trilling was on leave of absence in the fall term. We welcome them back.

We are pleased to report that Assistant Professors Lena Valavani and Daniel Hastings were promoted to Associate Professors effective July 1, 1988.

Dr. Harold Alexander, who is currently conducting research in the area of automatic control and robotics for Professor Robert Cannon at Stanford, has accepted our offer to join our faculty. He will be assigned to the Instrumentation, Guidance and Control Teaching Division. Dr. Michael Graves, who has been a structural engineer at the Boeing Company, and has made major contributions to the process of designing structures fabricated from modern composite materials, has also agreed to join our faculty. He will be assigned to the Structures and Materials Division.

As of July 1, 1988 the Department faculty consisted of 20 full professors (not counting Dean Kerrebrock and Professor Ezekiel, the Director for the Center for Advanced Engineering Study), six associate professors, and nine assistant professors. We are currently one over the complement contained in the Dean's manning table.

In our last three reports we discussed the Department's man-powered airplane project. Project Daedalus had as its goal the construction of a man-powered airplane that could fly from Crete to the island of Santorini, off the coast of Greece. This distance is about 74 miles, and exceeds slightly the distance mythology tells us that Daedalus flew in his escape from Crete. With the financial sponsorship of United Technologies Corporation, two aircraft were built. After suitable flight testing at Edwards Air Force Base in January, the aircraft were disassembled and flown to Crete by the Greek Air Force where they were reassembled by the Daedalus Team under the supervision of Professors Mark Drela and Steven Bussolari, and Project Manager Dr. John Langford. The team was transported courtesy of Olympic Airlines. On April 25, 1988, after nearly eight weeks of waiting, the weather was deemed favorable by Professor Bussolari, and the decision was made to make the attempt. Kanellos Kanellopoulos made the flight in record time. The flight was marred by the loss of the aircraft in the landing phase when the aircraft encountered strong gusty winds near the beach at Santorini island. The flight was a success. We all bask in the glory reflected from the accomplishments of the members of the Daedalus team and we are all proud of their achievements.

The Wednesday noon Faculty Luncheon meetings continued with Professor Markey's outstanding job in making the arrangements. This year he invited representatives of other Departments in the School of Engineering to describe their undergraduate course of study, and their expectation for its evolution. At the same time, members of the Department faculty studied the evolution of our course of study and concluded that at this time our undergraduate course of study was in good condition. Nevertheless, we felt the undergraduate instruction in astronautics could be enhanced by the addition of a subject in satellite thermal balance and communication. We hope to have a syllabus in the former area in time for next year's catalogue. It seems likely that the latter subject can be covered by an existing subject in Course VI. Professor Young is planning a senior elective to serve as an introduction to the subject of the man-machine interface.

Professor E.F. Crawley led an interdepartmental team that prepared a winning proposal for NASA Center for Space Engineering Research.

We were privileged to have Professor Sears give a general seminar on the History of Unsteady Aerodynamics. Professor Emeritus C.F. Taylor gave an excellent and well-attended seminar on the early days of aeronautics. In addition to all the Department meetings, the Divisions and Laboratories continue to sponsor their own seminars and working groups.

We had two community affairs this year; the celebration of Professor Emeritus E.S. Taylor's 85th birthday, and an alumni dinner celebrating the 50th anniversary of the Wright Brothers Wind Tunnel at the end of the term. In total, about 300 alumni and friends of the Department were our guests on these occasions.

UNDERGRADUATE PROGRAM

As shown in the table below, the undergraduate enrollment has dropped off substantially this year, which is a completely different pattern from the past.

Table
Undergraduate Enrollment over the Last Seven Years

	1981-2	1982-3	1983-4	1984-5	1985-6	1986-7	1987-8
Sophomores	91	86	100	99	106	120	96
Juniors	73	86	81	90	92	103	118
Seniors	62	85	81	93	106	98	105
Totals	226	257	262	282	304	320	319

The current fraction of women in the graduating class is 0.16, which is a little higher than last year's fraction of 0.13. The current average women's enrollment for all three classes is 0.27.

Mr. Scott A. Miller was selected for the Doolittle Scholarship award. His outstanding academic record and his contributions to the Department made him an attractive candidate. He continues the tradition of excellence we have come to expect of the Doolittle Scholarship holders.

Mr. Ricardo J. Zemella and Richard Gueler were awarded NSF Graduate Fellowships. We are pleased such recognition has come to these students.

About one-third of our faculty continue to be actively involved with freshmen in one way or another. The Department commitment to this activity remains strong.

GRADUATE PROGRAM

The number of graduate students continues to decrease somewhat, in accordance with our plans to reduce the number to about 180, or about an average of five per faculty. The current level is 203. Compared with our graduate registration of 230 four years ago, we are well on our way to our goal.

FACULTY NOTES

Professor R.H. Battin - Selected to give the von Karman Lecture for the American Institute of Aeronautics and Astronautics (AIAA) in January 1989.

Professor R.W. Simpson - Commencement Speaker, Hawthorne College, Astoria, NH.

Professor John Dugundji - Distinguished Lecturer at the Northwest Polytechnic University, Xian, China.

Professor P.A. Lagace - Editorial Advisory Board for Encyclopedia of Composites.

Professor Mark Drela - Aerodynamic design of Daedalus aircraft.

Professor E.F. Crawley - Chairman, Structures and Dynamics Technical Committee of ASME Gas Turbine Institute.

Professor A.R. Odoni - Co-edited a book with Drs. Beaco and Szego, Flow Control of Congested Networks.

Professor E.M. Greitzer - Named Slater Professor of Aeronautics and Astronautics.

Professor E.M. Murman - 1) Co-edited a book with Dr. Rizzi, Vol 12 of IMA Volumes in Mathematics and Its Applications. 2) Co-authored a paper, selected as Outstanding Paper of the Year by AIAA Applied Aerodynamic Panel. 3) Co-author of a "Citation Classic" paper with J.D. Cole.

Professor J.W. Mar - NASA Public Service Award for work on the Filament Wound Booster Case.

Professor S.E. Widnall - 1) Bradford Washburn Award, Boston Museum of Science. 2) Elected Fellow, American Academy of Arts and Sciences.

Professor J.R. Baron - Appointed to USAF Scientific Advisory Board.

Professor W.W. VanderVelde - 1988 Educator Award of the American Automatic Control Counsel.

Professor T.H.H. Pian - Major Lecturer at 16 universities in China.

Professor L. Trilling - 1) Winfred and Atherton Beam Visiting Professor of Science, Technology and Society, Carlton College. 2) Chairman, Council for the Understanding of Technology in Human Affairs.

Professor Lena Valavani - Appointed Boeing Assistant Professor.

EUGENE E. COVERT

Department of Chemical Engineering

The educational and research programs of the department continue to evolve to meet the changing demands for chemical engineers. We have increased our emphasis on educating both undergraduate and graduate engineers with broad-based multi-disciplinary knowledge and skills that can influence the development of new technologies and help rejuvenate older ones. Changes in the undergraduate curriculum aimed at emphasizing this goal are being implemented. These changes are an outgrowth of an extensive curriculum review carried out by a committee chaired by Professor L.B. Evans.

The undergraduate enrollment has continued a slow decline. The graduate population has remained stable at approximate 220 with a large emphasis on doctoral students (170). We anticipate a decline in this number because of a steady decrease in the number of students admitted into the program. The quality of the graduate program is very high. We have become the leading supplier of young faculty in the country, with our former students recently accepting positions at the University of California at Berkeley, Cornell, Minnesota, Princeton, Delaware and RPI.

The Practice School continued to operate major stations at Dow Chemical Company in Midland, MI and General Electric Corporation in Albany. Other stations were run during the summer at Sandia National Laboratories, Solar Energy Research Corporation, and Syntex Chemicals. Fund raising for endowment of fellowships for the Practice Program has continued at a vigorous pace. Currently we have raised approximately \$5 million of the \$8 million goal.

Research in the department continued at a very high level with new emphasis on the analysis and processing of advanced materials. Professor Karen K. Gleason joined the department in September '88 as the H.P. Meissner Assistant Professor at MIT. Her area of interest is structure property relations in electronic materials and the use of solid-state NMR.

There was one retirement and two other faculty added to the department in '88. Professor Jack P. Longwell retired effective July '88, but will continue part time as a Senior Lecturer. Professors Robert S. Langer and Marcus Karel transferred to Chemical Engineering from the Applied Biological Sciences department. Professor Langer is an expert in biomedical and biochemical engineering and will strengthen our considerable efforts in these areas. Professor Karel's research is in food science and engineering. He will bring new problems into the curriculum and research programs of the department. Both will be involved in teaching and subject development in the fall of '89.

The department is actively involved in the planning of a centennial symposium and convocation in October '88 to commemorate the founding of the discipline at MIT by Professor Lewis M. Norton. The symposium will meet for two days and will involve the department faculty, distinguished researchers and educators from other universities and industry. The focus will be the intellectual foundations of our discipline and its role in past, present and future applications. The convocation on Saturday, October 8th will be composed of two parts, the first of which will highlight changes in education and research at MIT. The second will discuss the societal impact of our profession. All of our alumni and friends are being invited to the convocation and associated social functions. The program committee for the centennial is being chaired by Professor Clark Colton.

UNDERGRADUATE EDUCATION

The following table shows the trends in undergraduate enrollment:

	83-84	84-85	85-86	86-87	87-88
Sophomore	59	61	49	43	38
Junior	105	47	69	49	36
Senior	116	115	54	65	55
TOTAL	280	223	172	157	129

Although the job market has stabilized, enrollments are low. Sophomore enrollment for '88 - '89 is expected to be between 40 and 45 compared to the more optimal level of between 60 and 80.

Several changes in the undergraduate curriculum have been initiated as a result of a review of our program by a committee chaired by Professor Lawrence B. Evans. The purpose of the review was to identify changes needed to respond to the changing career opportunities anticipated for chemical engineers in the next decade. The committee found the majority of the curriculum to be well organized and to cover critically important material. Two changes were suggested.

In the first, the current introductory computer subject, 10.01, was replaced by a computer proficiency requirement that can be satisfied by successfully completing either a less broad subject, 10.001, an IAP subject, or a proficiency requirement. This change focusses instruction at the freshman level on the use of computers and the Athena System and away from the more ambitious scope of 10.01 which integrated computers into the solution of chemical engineering problems. The synthetic material will be covered in later subjects.

The major change in the curriculum is the introduction of two subjects, 10.361 and 10.362, called Integrated Chemical Engineering or ICE to replace the computer subject and traditional process design, 10.36. The scope of ICE is described below.

Integrated Chemical Engineering: ICE

Integrated Chemical Engineering is a two-semester sequence of subjects (10.361 and 10.362) to replace the traditional process design subject. The subjects will consist of five or six modules, each about a month in length and devoted to the solution of engineering problems in the context of specific industrial and environmental settings. The problems will cover a broad range and can include more of the new technology areas that chemical engineers are concerned with these days. Examples include clean up of a toxic waste dump site, design of a new polymeric product, scale-up of a biomanufacturing process, and design of a batch process. Another module will consist of the design of a traditional continuous commodity chemical plant.

Professor Herbert H. Sawin conceived the idea for ICE as a new way to teach engineering fundamentals, but integrated in the context of the problems they are used to solve. In the engineering science subjects students learn the basics of thermodynamics, transport phenomena, and reaction kinetics. Then in the senior year ICE courses these topics will be revisited and drawn together.

Students will be exposed to some new material in the ICE courses, including synthetic problem solving, engineering economics, process design, product engineering, computer simulation, and process control. The subjects will also address the social implications of technology, including engineering ethics, environmental and safety considerations, and marketing.

One of the advantages of ICE to the students is the introduction to the diversity of applications in chemical engineering. As currently structured, 7 faculty and staff (George Stephanopoulos, Evans, Kramer, Langer, Merrill, Sarofim, and Erhenfeld) will be involved in teaching the two subjects in the coming year.

ICE will be taught for the first time to a small group of students on a pilot basis in 1988-89. In 1989-90 the courses will be optionally available to all students. For the class of 1991 they 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.

GRADUATE EDUCATION

The following table shows graduate enrollment from 1983 - 1988.

	83-84	84-85	85-86	86-87	87-88
Masters	98	77	72	77	65
Doctoral	109	127	148	151	169
TOTAL	207	204	220	227	234

The total for 1987-1988 includes 71 foreign students, 36 female students, and 6 minority students (not including Asian Americans).

The graduate enrollment should begin to decrease substantially over the next several years because the number of students admitted into the program has decreased steadily since '85. For example, approximately 40 doctoral degrees should be granted in 1988, while only 35 students (excluding MIT five-year program) were admitted for fall '89. The decrease in graduate admission has been generated by our control of the size of our program and comes at a time when the number of quality students is low because of the low availability.

The Practice School

Operations at the Practice School continued full time at our stations in Midland, Michigan and Albany, New York, with about 30 students participating. Last year we opened three new stations on a pilot basis during the summer session to provide additional opportunities for 20 of our students. These stations were at Syntex Chemicals, the Solar Energy Research Institute, and Los Alamos National Laboratory. In addition, we have expanded fund raising efforts to provide fellowship support for students from a permanent endowment fund.

Project work at our field station at Dow Chemical's extensive chemical manufacturing facility in Midland, Michigan continues to provide challenges for our students and staff. Projects at the Midland Station have dealt with the wide range of products and processes that exist at Dow's Michigan plant. Our Midland station will begin its third year of operation this summer with over 40 students having participated in project work. Professor Jeffrey Feerer took over as director in February, 1987 working with Pat Bigot and Harry Fine as his assistants.

Our station in Albany at General Electric's Plastics and Silicones manufacturing plants in Selkirk and Waterford, New York continues its operation after 10 years with a total of over 300 students, 6 directors and 10 assistant directors participating. Professors Greg Mehos and Jean Leinroth are currently directing operations in Albany.

Last summer, two groups of ten students each participated in projects at four stations. One group attended the Albany Station for 2 months and then travelled to New Mexico for a unique 5-week experience at Los Alamos National Laboratory. The second group went directly to Denver, Colorado in June to our two new stations at the Solar Energy Research Institute (SERI) in Golden and at Syntex Chemicals in Boulder. Staff from our Albany, Midland, and from Cambridge assisted in these pilot operations. Professors Bob Hanlon and Greg Mehos directed operations at Albany with Harry Fine's help, while Jeff Feerer, Kevin Sparks, Pat Bigot went to SERI for June and July. Bob Hanlon then directed the Boulder Station at Syntex, with Jeff Tester and Charles Grigsby running operations in Los Alamos.

One very essential item affecting the vitality Practice School is our ability to support students during the Cambridge coursework portion (on average two semesters) of their degree program. Funds from the companies hosting the stations fully supports the students during their semester at the field stations, but funding for the Cambridge portion has come primarily from fellowship aid provided by a group of sponsoring companies and from departmental funds. We are now attempting to generate these fellowship funds from a permanent \$8 million endowment fund pledged by our alumni. We are over halfway toward achieving our goal with \$5 million in commitments. We are continuing to canvas the 2000 Practice School alumni through a grass-roots campaign in order to provide an opportunity for full participation.

RESEARCH HIGHLIGHTS

Understanding of the relationships between microscopic properties of solid and liquid materials and processing methods is playing an increasingly important role in chemical engineering applications, especially with respect to advanced materials. Several of our faculty are involved directly with this style of research; their programs are highlighted below.

Solid-State Materials:

Characterizing the microstructure of thin films is central to the development of atomistic models of film growth and processing chemistries. In particular, solid-state nuclear magnetic resonance (NMR) provides a unique problem of local bonding environments, particularly in materials lacking long-range order. Three graduate students, under the direction of Professor Karen Gleason, are constructing an NMR spectrometer to obtain quantitative information on composition, elemental distributions, bond angles, bond lengths, site symmetry, coordination number, and molecular motion in thin films used in microelectronic device fabrication. This data, coupled with the film's preparation history and optoelectronic characteristics, will allow detailed microstructure models to be developed. Hopefully, such models will be used to optimize current processes and evaluating novel ones.

Complex Fluids

A vigorous research program in the field of Complex Fluids has been initiated by Professor Daniel Blankschtein. The systems being studied include micellar solutions, microemulsions, protein solutions, polyelectrolytes and related colloidal systems. The program spans the fields of thermodynamics and statistical mechanics of fluid mixtures, colloid and surface science, and physical chemistry of macromolecules. A central goal of the research program is to emphasize the important interplay between theory, experiment, and application.

The field of Complex Fluids is of central importance to a broad spectrum of industrial, technological, and biomedical areas, including enhanced oil recovery, detergency, wetting, food, paint, and cosmetic technology, biomolecular separations, solubilization and transport of cholesterol in the body, and cataract formation in the eye lens.

This field also provides a new exciting arena for the synthesis of concepts and computational methods from a diversity of scientific disciplines including physics, chemistry, engineering, and biomedicine.

Viscoelastic Liquids

The research program of Professors Armstrong and Brown focusses on the fluid mechanics of the very elastic solutions and melts that arise routinely in the processing of polymeric materials and is aimed at understanding of the relationship between process flow conditions, the rheology of the liquid, and the finally properties of the finished solid. Research accomplishments of the group include the development of the first general numerical algorithm for solving complex viscoelastic flows and the detection of the mechanism for elastic fluid mechanical instabilities in flow through an abrupt contraction.

The research of eleven graduate students and a post-doctoral fellow is supported by Office of Naval Research, National Science Foundation, Dupont, and the Army Ballistic Research Laboratory. Facilities include a three-component laser Doppler Velocimeter system, a two-color birefringence apparatus, extensive rheological characterization equipment, and a mini-supercomputer system.

CENTENNIAL CONVOCATION

In 1888, Professor Lewis M. Norton of the MIT chemistry department started the first program of chemical engineering education in the United States. To celebrate the 100th anniversary, the Department plans to host a Centennial Convocation of Chemical Engineering Education. The Convocation will take place on Saturday of the Columbus Day weekend, October 8, 1988.

The celebration will begin with a reception on Friday evening. On Saturday, there will be two symposia on the MIT campus. One will cover chemical engineering as an academic discipline with perspectives on the past and current and future prospects. Topics will include changes being made in the way chemical engineers are educated at MIT as well as exciting new frontiers in research. The second symposium will deal with the societal impact of chemical engineering as part of the larger issue of the role of technology in economic prosperity and national competitiveness. The day program will conclude with an open house in the Department with laboratory tours and exhibits. In the evening, we will conclude our celebration with a reception and banquet at the Boston Museum of Science.

On the two days prior to the Convocation, the Department will also host a symposium on the intellectual foundations of chemical engineering. This symposium, which will be held off campus, will involve the Department faculty and a number of distinguished researchers and educators from other universities and industry. The proceedings of this symposium will be published in book form, and a summary will form part of the Convocation on Saturday.

FACULTY

Robert C. Armstrong and Jefferson W. Tester were both promoted to full professor this year.

Professor Karen K. Gleason joined the Department of Chemical Engineering as its newest faculty member in 1987. With her B.S. in Chemistry and an S.M. in Chemical Engineering from MIT, she obtained her Ph.D. from University of California, Berkeley and now serves as the H. P. Meissner Assistant Professor. She is building an NMR spectrometer in her lab and it is expected to be operational by early September. She has published articles in AIChE Journal, J. Applied Physics, Physical Review Letters, and others. Among her awards and honors are the Materials Research Society Graduate Student Award, the Amoco Foundation Fellowship, the NCAA Postgraduate Fellowship, the Warren K. Lewis Fellowship, and Corning's Women in Engineering Fellowship.

A number of faculty achievements during the year deserve special mention:

Professor Robert C. Armstrong was the Midwest Mechanics Seminar Series Lecturer this spring, giving seminars at the University of Minnesota, University of Wisconsin, University of Michigan, Michigan State University, University of Illinois, Purdue University, Illinois Institute of Technology, and Notre Dame. In addition he gave keynote lectures at the International Polymer Processing Society Meeting in May and at the Schlermberger Oilfield Rheology Meeting in Cambridge, England.

Professor Janos M. Beer was invited by the Finnish Academy as a member of a committee of four to evaluate the scientific research of Finnish Universities and National Laboratories in the area of energy production and utilization.

Professor Howard Bremner received the 1988 American Chemical Society Award in Colloid or Surface Chemistry sponsored by the Kendall Company. A special three-day symposium was held in his honor at the Colloid and Surface Chemistry Division of the American Chemical Society at Pennsylvania State University. He also received a Guggenheim Fellowship for the purpose of writing a book on "Macrotransport Processes."

Professor Robert A. Brown was appointed Executive Officer for the Department of Chemical Engineering in July of 1987. He was Robert W. Vaughan Memorial Lecturer at the California Institute of Technology last October and was appointed to the Editorial Board of the Journal of Scientific Computing and to the Advisory Board on Advanced Scientific Computing to the National Science Foundation.

Professor Adel Sarofim delivered invited plenary lectures at the joint meeting in Amalfi of the French and Italian sections of the Combustion Institute in June, 1987 and at the Australian Coal Science meeting in Adelaide in May, 1988.

Professor George Stephanopoulos was the ICL Distinguished Lecturer at the University of Alberta, Edmonton, Canada, and the 9th Centennial Lecturer in Process Systems Engineering, University of Bologna, Italy. He also became a Member of the Editorial Board of Artificial Intelligence in Engineering.

Professor Daniel I. C. Wang was the L.T. Pirkey Centennial Lecturer, Department of Chemical Engineering at the University of Texas, Austin in 1987, the Donald L. Katz Lecturer, Department of Chemical Engineering at the University of Michigan in 1987, the Braverman Memorial Lecturer, Technion Institute of Technology, Haifa, Israel in 1987, and the Plenary Lecturer at the International Conference on Separations for Biotechnology, Reading, England.

Professor James Wei, Chairman of the Department, served as President of the American Institute of Chemical Engineers this year, and was Commencement speaker at the graduation ceremony of the School of Engineering at the University of Delaware in May 1988.

STUDENTS AND STAFF

Institute-Wide Awards

Sherill L. Briese ('90) received one of two Eastman Kodak Scholarships awarded to sophomores in the MIT School of Engineering recognizing academic and personal excellence. Six students were elected to Tau Beta Pi, the Engineering Honorary Fraternity for excellence in academics: Tina Berceci ('88), James Donovan, Michael Gobler ('89), Peter Kofinas ('89), Jeffrey Prible ('89), and Mary Beth Wall ('88).

Departmental Awards

George Li ('89) received the Dow Chemical Outstanding Junior Award, which recognizes achievement in academics, leadership, and campus activities. The AIChE Annual Chapter Scholarship Award for highest scholastic performance through the first two years was given to Michael Gobler ('89). The Texaco Philanthropic Foundation Scholarships recognizing excellence in academic performance by students who have completed their junior year in Chemical Engineering were awarded to Wendy Sanford ('89) and Linda Yeh ('89). Kamran Badizadegan ('88) received the Robert T. Hanslam 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 Mary Beth Wall ('88). The oldest prize in the Department, named for Roger deFriez Hunneman, recognizes outstanding scholarship and research. This year's recipient was Lisa Vingerhoet ('88). Thomas Spitznagel ('88) received the Chemical Engineering Department Special Service Award for his work as President of the Student Chapter of the AIChE.

Graduate students receiving awards were Karl Graham, Deborah Savage, and Mike Barrera. Karl received the Rosemary J. Wojtowicz Award for exemplary performance in his project work at the Practice School. Deborah was recognized for her work as President of the Graduate Student Council, and Mike for his efforts in coordinating intramural athletic activities.

The Outstanding Employee Award was given to Elizabeth Marshall for exceptional service to the Department. Professor Robert A. Brown received the Outstanding Professor Award, presented annually by the Graduate Student Council.

JAMES WEI

Department of Civil Engineering

Introduction

The Department of Civil Engineering continues to maintain and expand its leadership role in education and research for its profession. The evolving trends in hazardous waste management, environmental control, large scale infrastructure renewal, transportation systems, and new construction are combining to provide us with important new ways to develop and spread new technology, to learn from ongoing work, and to provide our students with abundant, well paying jobs. Over the next ten years, the Boston area will be one of the main centers for civil engineering in the nation with the three billion dollar Central Artery depression, the Third Harbor Tunnel, the six billion dollar Boston Harbor Clean Up Project, as well as numerous private sector projects. In addition, many of the major environmental engineering firms involved in the hazardous waste clean up process are headquartered in Boston. We are cooperating with our profession to find new ways to increase productivity, creativity, reliability, cost effectiveness, performance, and safety in these projects. This involves ways of increasing interaction between design and construction through the use of computers and artificial intelligence; instrumentation studies for monitoring hazardous waste movement; new understanding of the fate and transport of hazardous waste movement in the ground water; technology for assessing the performance and condition of roads, pipelines, underground storage tanks and bridges; new materials for construction; new ways of managing goods and people in networks; and new ways of managing and controlling excavation. The Department, through its careful planning over the last several years, is well prepared and well positioned to help, and lead, its profession in these important projects as is evidenced in the following sections detailing our activities over the past year.

Undergraduate Education

The Department's new Undergraduate Program has now been in place for two years and continues to evolve and become more definitive. Our unified Sophomore Core of solid mechanics, fluid mechanics, economics, computers, and probability has been augmented with a Junior Core consisting of options in ecology, structures, soil mechanics, materials of construction, and fluid dynamics. New electives in engineering computation have been added as well.

The Department has also developed and offered, for the second year, a program in Engineering Systems and Computation (ESC) as an undesignated IA program. It is designed for students who wish to have a broad based systems and computation program but do not wish to satisfy all of the requirements for the SB in Civil Engineering. This year was the first year for another IA program in Environmental Science and Engineering which builds on the Department's strengths in fluid mechanics, environmental chemistry and biology, ecology and hydrology, 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), and Urban Studies, Economics, Management (policy aspects). These revised and new programs not only provided leadership in educational programs for the profession and for these areas at MIT, but have also led to a significant increase in students. This year, based on preliminary counts, the number of freshmen choosing Civil Engineering has increased to 30 (up from 19 last year at this time - an increase of 57%).

Our faculty continue to provide service to the Institute community as well as to our own undergraduates. Subject 1.00 Introduction to Computer Systems is a popular subject which now educates more than 300 students per year and is now the largest non EE basic Institute computer subject. We have also taken over responsibility for the School of Engineering's school wide Subject 1.12 Computer Models of Physical and Engineering Systems. Professor Sallie Chisholm reports that her Subject 1.80 Ecology has seen a doubled enrollment in students; reflecting a renewal of undergraduate concern for environmental matters regardless of their Department.

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 has been formed drawing on division faculty to address the problems of the construction industry. In addition to their own graduate educational programs, each division also cooperates in interdepartmental educational programs as well. Members of the Transportation Systems Division make up a significant part of the educational program and faculty involvement of the Center for Transportation Studies, and they provide leadership for the

School of Engineering's Technology and Policy Program. In addition, they make significant contributions to the Operations Research Center and to the Masters of Science in Technology Educational Program. Members of the Constructed Facilities Division are helping to begin a joint Civil Engineering, Architecture, and Mechanical Engineering effort in Building Systems. Members of the Water Resources and Environmental Engineering Division are heavily involved in the interdisciplinary Hazardous Substances Management Group. This group has started a four subject educational program, with few prerequisites, entitled Chemicals in the Environment aimed at undergraduates and first year graduate students. Professor Harold Hemond has developed a new subject 1.725J Chemicals in the Environment: Fate and Transport as part of the sequence. There is also heavy involvement by the Division in the programs of the Joint MIT- Woods Hole Oceanographic Institute Educational Program.

September 1987 marked the completion of five full academic years of the Center for Construction Research and Education's direction and administration of the graduate degree programs in Construction Engineering and Management. These programs, which lead to the SM, Engineers, and Doctors Degrees, help prepare students for a variety of career opportunities in the construction industry. CCRE graduates occupy management, technical, and professional positions not only in construction firms but also in owner organizations, government agencies, engineering and design firms, and other companies that supply important materials, products, and services to the industry. In addition, a significant increase in the number of Ph.D candidates in our program provides strong evidence of increasing interest and opportunities in teaching and research careers in the field of construction engineering and management. In 1987-88 we had 29 SM and 20 Phd Candidates. Due to the need for students to have a good understanding of the construction industry, we have asked industry to help us in the educational process. Last year the firm of Parsons, Brinckerhoff, Quade and Douglas participated in "Case Studies in Heavy Construction," and the Badger Corporation in "Project Execution in the Refinery and Petrochemical Industry."

Research

Instead of focusing on research by the divisions this year, I present information about some of the Department's major research initiatives to give an idea of the vitality and international importance of these efforts.

Hazardous Substance Management

This area continues to be of supreme importance to the future health of our population. Millions of tons of improperly disposed of chemicals are buried in the ground or discarded on the surface where they can kill the air we breath; either by direct contact, or, by transference to humans in the water supply. We have joined with Chemical Engineering, Toxicology (Whitaker College), and Urban Planning, in numerous ventures in this area. We are leading a major field study in the Aberjona River Basin (Woburn, Mass) in suburban Boston, which we expect to follow for many years to come. Our role is to hindcast and forecast transport and transformation of contaminants over a large region so as to guide and complement studies of human toxicology and of remediation technology. This will involve experience in experimental design, sampling and analytical chemistry and a concerted effort in theoretical, laboratory, and field investigation of the determinant physical, chemical, and biological processes. Our ultimate product will be a coherent mathematical model of all transport and transformation mechanisms. This project has the potential for becoming an archetypal case study for the methodological analysis of an urban environmental region long suffering from improper waste disposal. In addition to the Aberjona project, we have at least 15 more ongoing projects addressing physical, chemical and/or biological aspects of contaminant transport in ground water. These projects range from detailed studies of colloidal particles and of multi-fluid interfacial dynamics at the pore scale to predictive models of contaminant transport at the field scale with concomitant field studies to test and validate the predictive models. Each of these projects contributes to our overall goal of providing reliable engineering tools to assess and mitigate hazardous waste contamination problems.

Infrastructure Provision and Renewal

The nation's extensive existing and needed new infrastructure (bridges, dams, highways, airports, pipelines, buildings, etc.) benefited from numerous Departmental research projects this year. The joint activities of the Center for Construction Research and Education, and the Center for Transportation Studies have pulled together a New England Surface Transportation Infrastructure Consortium of five New England State's transportation agencies, universities, and MIT to focus them on integrated regional specific R&D, technology transfer, and educational programs. A particularly

important project, under the supervision of Dr. Kenneth Maser, is concerned with the use of new technologies to assess the condition of bridge decks. Using radar, lasers, and thermography, 31 bridge decks slated for replacement were surveyed and then destructively tested. Combinations of these technologies were shown to do an excellent job at revealing the extent of poor concrete conditions, rusted reinforcing bars, and delaminations hidden from the eye. Additional research in the theoretical aspect of use of these tools, on the data management needs of condition assessment programs and on new materials for infrastructure maintenance and repair are also underway. Examples are Michael Markow's work in advanced ceramics in construction, Professor Moshe Ben Akiva's work in the role of uncertainty in management of infrastructure facilities, Professor Eduardo Kausel's work in non destructive testing via electro magnetic wave forms, and Professor Harris Koutsopoulos's work in urban traffic control.

Advanced Construction Technology

We are now in our second year of a major \$15 million/five year program with the US Army Research Office which has established a program for Advanced Construction Technology. This program provides for fellowship funds for US students doing Ph.D work in construction technology, \$3 million in equipment funding, and large amounts of internally administered funds for faculty research in this area. We are currently funding 11 faculty members in areas of construction materials, intelligent systems, robotics and in situ testing, infrastructure, and construction industry technology policy. This work has attracted many students and faculty, and is clearly acting as a seed for technology research that will change the direction of the MIT program, as well as the industry for some time to come.

The Department is also playing a major role in the establishment of a joint Civil Engineering, Architecture, and Mechanical Engineering program in Building Systems. The goal here is to bring better definition and integration between the various disciplines that create, engineer, provide technologic systems, construct, and maintain buildings. In the fall, a major set of initiatives revolving around buildings with important technologic components (clean rooms, vibration free requirements, other environmental needs, electronic shielding, etc.) and buildings that house rapidly evolving research and development will be started. A major focal point will be the use of the new Science Complex (a new building for Biology plus renovation of existing space for Physics and the School of Engineering) as a case study and integrating metaphors for our joint efforts.

Intelligent Engineering Systems

This major initiative deals with the promotion of education and research required to improve the quality and productivity of engineering and construction through advances in information sciences, artificial intelligence, and computer technologies. A particular focus is to develop and evaluate methods for simulating intelligent engineering problem solving in computers. Examples are: Professor John Slater's work for Project Athena in Structuring Engineering Tutoring Systems for students at the undergraduate and graduate level, Professor Robert Logcher's work in Natural Language Interfaces in Construction Databases, and Dr. John Williams' work (with Professor Alexander Pentland of the Media Lab) in Construction Simulation. Dr. Williams' work represents a new way of looking at computer aided design in that it allows data representation and object manipulation in a way that the computer can be used in the innovative process of design before there is a formal move to final representation, specification, sizing and drafting. Several faculty are working on design and analysis advisors that provide expert advice for engineers. Typical projects include: qualitative evaluation for earthquake resistant analysis and design (Professor Kausel); conceptual design of highrise buildings, bridges, and offshore structures (Professor Duvvuru Sriram); design of reinforced concrete and partially prestressed structures (Professor Oral Buyukozturk); finite element and boundary element modelers (Professors Slater and Jerome Connor); and design of hazardous waste disposal units (Professor David Marks). All this work is evolving towards a better understanding of design so that the computer, computer science approaches, and artificial intelligence can be used to help educate engineers and increase their productivity, innovation, and quality control.

To reduce cost while improving productivity and safety in construction, Professor Slocum is working on a series of construction productivity aids including the WALLBOT (robot to build walls), the BLOCKBOT (robot to build masonry walls) and STUDWELDER (robot to weld studs). Here, additional emphasis is placed on problems of large-scale metrology. Full scale prototypes of these machines are currently being designed, built, and tested by students from a variety of Departments.

Advanced Materials for Construction

Engineering design and construction is based on the paradigm of using naturally occurring materials put in place by humans. Our work in robotics is seeking to automate some of the human tasks. New advances in engineered materials, i.e., materials that are manufactured, perhaps on site, for special uses make it possible to change the way we consider construction. Professor Victor Li is working in fiber reinforced concrete and ceramics to provide better, more reliable structural materials. Professor Lorna Gibson is working on lightweight structural sandwich panels more amenable to robotic construction. Professor S. Shyam Sunder is working on the mechanics of damage in construction materials, as well as new work in polymers and plastics for construction use.

There are many other examples of the vitality of our research and educational initiatives. Our Transportation Systems Division is making significant inroads in logistics, a new half-million dollar wave tank has been installed in the Parsons Laboratory, the Geotechnical Group of the Constructed Facilities Division will be heavily involved in new slurry wall construction methods for projects like Post Office Square and the Central Artery in Boston. Several faculty members using new methods developed at MIT are deeply involved in important siting, prediction, and modeling issues for the Boston Harbor Clean Up Project. All in all this has been an exciting and vigorous year.

Department Administration

Department Head, Professor David H. Marks
Chairman of the Undergraduate Program, Professor Keith Stolzenbach
UROF Coordinator, Professor Harold Hemond
Chairman of the Graduate Program, Professor Ole Madsen
Admissions Officer, Professor Charles C. Ladd
Coordinator, Student Chapter of the 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, Head of the Center for Technology, Policy and Industrial Development; Professor Richard deNeufville, Head of the Technology and Policy Program; Professor Steven Lerman, Head of the Athena Computers in Education Program (through 6/30/88); 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; Professor Herbert Einstein, Head of the REMERGENCE Interdepartmental Experimental Facilities; Professor Fred Moavenzadeh, Head of the Technology and Development Program; and Professor W. Kendall Melville, Head of the Joint MIT Wood's Hole Program in Ocean Engineering

Faculty and Staff

One new faculty member started this year: Assistant Professor Harris Koutsopoulos joined the faculty in July 1987 in the Transportation Systems Division.

Two resignations were received this year: Assistant Professor Sue McNeil left in January 1988 to become Assistant Professor of Civil Engineering at Carnegie Mellon University, Pittsburgh, Pennsylvania. Assistant Professor John H. Slater left in June 1988 to join the engineering firm of Stone and Webster in Boston.

Several Faculty were on leave: These included Professor Logcher (Spring 1988 Sabbatical) Professor Gschwend (Spring 1988 Sabbatical); Professor Gregory Baecher (Spring 1988 leave); and Professor Mohsen Baligh (Fall 1987 Sabbatical, Spring 1988 leave).

Some Departmental Statistics

Number of Faculty: 40 (June 1988). This is the lowest in some time. We have reached the Department's goal, to reduce overall faculty by 10% in the School's program, several years earlier than the 1992 goal. Number of Undergraduates, Fall 1987: 85. Expected Fall 1988: 100.
Number of Graduate students, Fall 1987: 244. Expected Fall 1988: 240.
Department Research Expenditure for AY 1987-88: \$5,553,000.

Notes About Individual Faculty Members

Professor Rafael Bras, in December 1987, organized a successful symposium on Fluvial Geomorphology at the fall meeting of the American Geophysical Union. This summer he will host a conference on Natural Disasters in Mediterranean European countries in Italy, and a September conference on Mesoscale Precipitation, co-sponsored by the American Meteorological Society and the AGU. Professor Bras just finished his book Introduction to Hydrology and is editing a special issue of the Journal of Hydrology on "Research in Hydrology - the US-Japan Experience."

Professor Michael Celia was the winner of the 1987 Departmental Outstanding Teaching Award. He organized the Seventh International Conference on Computational Methods in Water Resources held at MIT in June 1988. He also organized the Department's Summer Undergraduate Fellowship Program in Civil Engineering which is aimed at attracting top undergraduate students from other universities to MIT for a summer of research and, hopefully, graduate work at MIT. He is finishing up a textbook on numerical modelling in ground water systems (with William Gray of Notre Dame). Professor Celia is a winner of the prestigious National Science Foundation Young Presidential Investigator Award which provides \$100,000/per year of funding over a five year period.

Professor Sallie Chisholm has succeeded in a major discovery of a very small (less than 1 micrometer in diameter) novel phytoplankton group which numerically dominates the deep waters of the oceans. The existence of these cells was unknown until she detected them using sea-going flow cytometry; and they appear to have a very unique taxonomic status - a "missing link" of sorts. Moreover, they could be a very important component for the marine food web.

Professor Richard deNeufville continues his major effort in leading the Interdepartmental Technology and Policy Program; an educational initiative with 60 students in a two year MS course. He is also involved in advising the new Australian Federal Airports Corporation which now owns and operates all the principle airports in Australia.

Professor Peter Eagleson continues in his two year term as President of the American Geophysical Union. This year saw the AGU take its first formal involvement in public policy through a position statement on the need for a global space and land based observation system to monitor global environmental change. Professor Eagleson is also Chairman of a National Academy of Sciences/National Research Council Committee on Opportunities in the Hydrologic Sciences.

Professor Herbert Einstein is Head of the Interdepartmental REMERGENCE Laboratories and has developed a Physical Geology Educator module for the Engineering Geology Tutor, Part of the Athena Cats Computer Aided Education System. He is the Co-editor of Rock Mechanics and Rock Engineering.

Professor Lynn Gelhar continues to emphasize large scale field studies, including saturated zone studies, in cooperation with the US Geological Survey on Cape Cod and the Tennessee Valley Authority in northwestern Mississippi. A major unsaturated zone experiment, in cooperation with New Mexico State University, is also underway in the desert of southern New Mexico. Professor Gelhar is completing a textbook entitled Stochastic Subsurface Hydrology.

Professor Lorna Gibson is contributing to a major interactive program with Architecture and Mechanical Engineering, in Building Systems, where her interest in lightweight building materials is finding new applications in automated building. She has just had her book (with Michael Ashby of Cambridge University) Cellular Solids: Structure and Properties published by Pergamon Press. It describes the modelling of materials with a cellular microstructure (both man-made honeycombs and foams and natural materials such as wood, cancellous bone, cork and leaves) and shows how modelling can be used to select foams in several engineering applications (thermal insulation, packaging, and lightweight sandwich panels for construction).

Professor Philip Gschwend continues his work for multiple sponsors in understanding the role of colloids in groundwater transport of toxic chemicals. The findings of his research team have influenced a substantial change in the way groundwater sampling is performed at hazardous waste cleanup sites. He is also working on the question of the long term hazards associated with the highly contaminated bed sediments like those in Boston Harbor. He is finishing his book "Aquatic Organic Chemistry" which he is writing with Rene Schwartzenbach of the ETH in Zurich, Switzerland.

Professor Donald Harleman is working on the modeling of water quality in rivers and lakes. One important problem is the study of eutrophication problems in Wachusetts Reservoir; a major element in the Boston area water supply. The research will focus on the simulation of various strategies to control increasing problems with taste and odor. He is also leading an effort on the important engineering/public policy problem concerned with the cleanup of Boston Harbor. He has been arguing that the present plan is too expensive and too involved for the problem at hand and is working at several levels to bring the issue to public debate and scrutiny.

Professor Harold Hemond continues his work in the development of an in situ probe for detection of hazardous wastes in the groundwater. Major advances have been made in mass spectrometer performance, a drivable probe, and the spectrum separation algorithm. Construction of the suitcase sized portable mass spectrometer has started. In his work in acid deposition (rainfall), a novel trace application of Radon-222 has helped constrain possible, as well as identified, sites of apparent fracture flow.

Professor Eduardo Kausel has evolved into new areas of infrastructure analysis focusing on wave propagation techniques for assessing the condition of built facilities such as pavements and bridge decks via remote sensing.

Professors Charles Ladd, and S. Shyam Sunder have led the change of the Center for Scientific Excellence in Arctic Offshore Engineering from one solely supported by British Petroleum - to a consortium of oil companies involving Amoco, Arco, Conoco and Mobil. The Center deals with the structural and geotechnical problems of exploration and production of resources in cold environments. This ability to keep research alive (in a period of poor performance for oil companies) is very significant and shows the long term interest in energy extraction in the Arctic.

Professor Victor Li's work in fracture mechanics in earthquake and concrete problems has been highlighted by his service on several committees for the American Concrete Institute (ACI); the International Union of Testing and Research (RILEM); the American Geophysical Union (AGU); and the Society of Experimental Mechanics (SEM). He has served as Co-Chairman of the Committee on Mixed Mode Fracture Mechanics for SEM, as Member of the Advisory Board for the International Conference in Fracture of Concrete and Rock (RILEM), on Committee 446 on Fracture Mechanics (ACI), and the Committee on Fracture Testing Standardization (RILEM).

Professor Ole Madsen has just finalized a five year contract with the Coastal Engineering Research Center of the US Army Corps of Engineers in Vicksburg, Mississippi, for "Calculation of Bottom Boundary Layer Properties". This long term relationship again indicates the importance and quality of the research being carried out.

Professor Dennis McLaughlin has developed new real time estimation and control applications to predict the movement of complex groundwater contamination plumes at two field sites (Otis Air Force Base on Cape Cod and a Canadian site). He is involved with Professor Gelhar and Professor Celia on a long term Nuclear Regulatory Commission multi-year study on the characterization of low-level radioactive waste sites.

Professor Chiang Mei was the Keynote Speaker at the International Union of Theoretical and Applied Mechanics Conference on Nonlinear Waves, in Tokyo, Japan, and at the National Summer Workshop on Hydrodynamics in Canton, Peoples Republic of China.

Professor W. Kendall Melville has returned to MIT from a Sabbatical leave to initiate six new research grants. One of these is from NASA to study, with Professor Jin Kong of Electrical Engineering, certain aspects of radar altimetry in oceanographic applications. It involves a significant field component which will be undertaken from offshore platforms.

Professor Fred Moavenzadeh is winding up a ten year association between MIT and Cairo University. In that time, numerous research projects in various sectors such as water resources, transportation, communications, electric power systems, housing, health care and the construction industry were carried out jointly by MIT and Cairo University Faculty. This massive project (over \$28 million in MIT research funds) was sponsored by the US Agency for International Development. Its work is considered a definitive and successful model of inter-country academic and governmental agency development.

Professor Francois Morel supplied the leadership to organize and evolve our interdepartmental work in the hazardous waste area for the successful joint proposal, with Chemical Engineering and Toxicology, to the National Institute for Environmental Health Sciences. Professor Morel's student, David Dzombak, received the Best Thesis of the Year Award from the Association of Environmental Engineering Professors.

Professor Yosef Sheffi has contributed greatly to our new Undergraduate Program in Engineering Systems and Computation. His work in logistics has brought considerable new private sector interest and affiliation with the Center for Transportation Studies.

Professor S. Shyam Sunder has completed the funding and construction of the first phase of a Low Temperature Materials and Structural Testing Facility. It consists of three cold rooms, and allows precision temperature control in the range of -40 C to 0 C. It is used for the Department's ongoing work in Offshore Structures in the Arctic and for the study of ice as a material, and as a surrogate, for damage investigations for a variety of construction related materials. He also is developing new work in the area of molecular dynamics associated with the formation and growth of interface bonds involving ice in a search for ways to prevent ice formation on constructed facilities. In the area of construction polymers, he is working on adhesively bonded joints to increase the durability of joints in large roofing systems.

Professor Alex Slocum, our Macomber Assistant Professor in Construction, has just won a National Science Foundation Young Presidential Investigator Award, bringing the Department total to two. Professor Slocum continues his work on productivity and automation aides for construction. His Wallbot, a machine for erecting drywalls for interior finishing in buildings, was recently featured in Popular Science and represents the first major automation inroads in this area.

Professor Duvvuru Sriram has helped to form the Department's new Intelligent Engineering Systems Laboratory and is working on an industry consortium in the area of applied artificial intelligence. He is completing work as editor on several conference proceedings on knowledge based expert systems for engineering.

Professor Keith Stolzenbach is leading a consortium of local universities in building an extensive research and monitoring program focused on Boston Harbor; progress has been slow, but, the State has now allocated \$2 million over the next two years.

Professor Nigel Wilson has strengthened relationships between the MBTA and MIT in the area of transit research with the start of a new research project to examine existing operations planning, and operations control procedures on the Green Line and to develop new control procedures both for immediate use and for longer-term implementation.

DAVID H. MARKS

Department of Electrical Engineering and Computer Science

Undergraduate enrollments in Electrical Engineering and Computer Science (EECS) have declined after a decade of relatively large enrollments. Enrollment in the sophomore class in Fall 1987 was about 280, near our goal of 270 for each class. It now appears that the incoming sophomore class will be even smaller, about 230 students. Most of the decline is in EE students -- the CS population has been relatively stable for over a decade. While this welcome decline is no doubt due in part to changes in MIT admissions, there is a similar decline in other EE departments around the country. We believe that the decline is, in large part, due to the major recession in the computer and electronics industries in 1985-86.

We note with pleasure a significant reduction in the number of EECS students in academic difficulty far greater than the reduction in enrollments would have predicted. The number of academic warnings sent to our undergraduates has been declining for the past three years, but is especially noticable in our current sophomore class. This may be a corollary to the decline in enrollments.

The Department has initiated an Experimental Masters Program in which students can earn an SM degree while working in local industry. All courses required for the degree are expected to be taken on campus. The SM thesis is to be jointly supervised by a company supervisor and an MIT faculty member. A major goal of the program is to enable more of our students to complete their undergraduate education with the Masters Degree experience. The costs of the program to the companies include paying part-time salary to each student working for them as well as full tuition and a fee. As a result of the relatively high cost of the program, only five students are expected to enroll in it next year. It is hoped that modifications in this program will enable it to expand to several dozen students per year.

UNDERGRADUATE PROGRAM

Enrollment of undergraduates averaged 1,000 in 1987-88, with about 67 percent in the Electrical Engineering Program and 33 percent in the Computer Science Program. The total represents a decrease of about 100 students from the previous year.

The following prizes and awards were won by our undergraduate students:

The Ernst A. Guillemin Prizes for the outstanding SB theses in Electrical Engineering were awarded to David Jay Reinkensmeyer of Centerville, OH (first prize), and Lin Li Liu of Manila, Philippines (second prize). Honorable mentions went to Karin Hollerbach of Fairbanks, AK, and to Tsen-Yu Hung of San Jose, Costa Rica.

The David Adler Memorial Thesis Prizes for Undergraduate Theses in Electrical Engineering were presented to Edward H. Nakamoto of Hilo, HI (first prize) and Peter H. Schmidt of Milwaukee, WI (second prize), with Honorable Mention to Lucene L. Tong of Brisbane, CA.

The William A. Martin Memorial Prize for the best thesis in Computer Science was won by Russel Schaffer of Colorado Springs, CO. The Charles and Jennifer Johnson Prize for the outstanding undergraduate thesis in Computer Science was presented to Waldemar Horwat of Hoffman Estates, IL. The Computer Systems Prize for the best undergraduate thesis in computer systems was awarded to Brian Totty of Baton Rouge, LA.

The George C. Newton Prize for the best undergraduate laboratory project was awarded jointly to Waldemar Horwat of Hoffman Estates, IL, and to Kenneth P. Lu of Rochester, NY.

GRADUATE PROGRAM

In September, 1987, there were 632 graduate students enrolled in the Department. Of this number, 192 were newly admitted. About 20 percent of the total were foreign nationals. The Department supported 284 Research Assistants and 107 Teaching Assistants. In addition, there were 134 fellowships including 41 National Science Foundation Fellows, 7 Hertz Fellows and 6 ONR Fellows. The remaining students had industrial or foreign support or were using their own funds.

During 1987, the Department awarded the following graduate degrees: 164 Masters of Science, 17 Electrical Engineers and 50 Doctorates.

The Department received 1,821 applications for the 1988-89 year. The applicants continue to be generally excellent and 272 were admitted, of whom we expect 216 to register for next fall.

A number of departmental awards were made to graduate students for excellence in teaching. Ruth Y. Shyu of Edison, NJ received the Carlton E. Tucker Award, while Jae K. Kim of Toronto, Canada received the Harold L. Hazen Award. Frederick C. Hennie, III Awards for excellence in teaching were presented to Kevin A. Delin of West Simsbury, CT, and Mostafa Terrab of Cambridge, MA.

Kevin Delin and Timothy Wilson were promoted to Instructor-G in recognition of their demonstrated teaching abilities and services to the Department.

VI-A INTERNSHIP PROGRAM

In its 70th year, the Department's VI-A Internship Program continued its popularity and excellence in 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, this number of applicants represents a larger percentage of the class than in prior years. Eighty-four applicants were admitted.

The mix of participating companies remained relatively stable. Last year, due to some uncertainties regarding future assignments to the David Sarnoff Research Center, no new students were assigned. This year, after a detailed review, assignments were reinstated and two new VI-A students have accepted assignments at the Center. With the sale of Schlumberger's Fairchild operation to National Semiconductor, VI-A assignments to the Fairchild locations were discontinued and a new Schlumberger location -- Schlumberger/Doll in Ridgefield, CT -- was added.

At this year's graduation 65 VI-A students received their degrees having completed all of their company assignments and their Institute degree requirements.

Each year MIT holds an Awards Convocation to recognize outstanding performance by students, faculty, athletes, and staff. One of the most prestigious awards for staff is the James N. Murphy Award. The award is given to an employee whose spirit and loyalty exemplify immeasurable contribution to community life at the Institute, especially with regard to students.

This year the selecting committee for the Murphy Award determined that Lydia O. Wereminski, Administrative Assistant in the VI-A Office, was the most deserving employee and the award, a large Paul Revere bowl suitably engraved, was made at an impressive ceremony.

VI-A students continued their excellence in academic achievements as attested to by the following list of awards.

Ruth Y. H. Shyu (Bell Labs.) - The Carlton E. Tucker Award to a graduate student in recognition for excellence in teaching.

Jae K. Kim (I.B.M./Yorktown Heights) - The Harold L. Hazen Award to a graduate student in recognition for excellence in teaching.

Lucene L. Tong (Raytheon) - Honorable Mention for the David Adler Memorial thesis competition.

Clifford K. Yang (Schlumberger) - Honorable Mention for the Writing Program's engineering writing competition. His paper was titled "Fidelity of Analog to Digital Conversion."

RESEARCH

Most research by our faculty is performed in interdepartmental laboratories. We estimate the total FY88 research volume on projects of which our faculty or research staff members are in charge to be over \$46 million, of which only \$4.2 million takes place under the jurisdiction of the Department. The bulk of the balance is allocated among the following interdepartmental laboratories associated with EECS:

<u>Laboratory</u>	<u>\$million (estimated)</u>
Artificial Intelligence Laboratory	7.8
Laboratory for Computer Science	9.8
Laboratory for Electromagnetic and Electronic Systems	2.1
Laboratory for Information and Decision Systems	3.5
Research Laboratory of Electronics	9.3
Plasma Fusion Center	10.0

In addition to the laboratories noted above, faculty research is also performed in other departmental or MIT-affiliated laboratories, namely: Energy Laboratory, Operations Research Center, Center for International Studies, Center for Materials Science and Engineering, Lincoln Laboratory, Francis Bitter National Magnet Laboratory, and Biomedical Engineering Center for Clinical Instrumentation (see Health Sciences and Technology (HST) Research Activities). Information on the work of all the interdepartmental laboratories mentioned above appears in other portions of this report, dealing separately with each one. However, the MIT Microsystems Research Center and Microsystems Technology Laboratories are departmental in organization and we therefore report below the highlights of their research for the past year.

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).

This year the level of research was close to \$10 million, and the technical areas included 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. Special events also occur from time to time: this year the university VLSI conference was held at MIT. The facilities that enable some of this research are supported in part by the members of the MIT Microsystems Industrial Group (MIG), including Analog Devices, Incorporated, AT&T, Digital Equipment Corporation, Eaton Ion Beam Systems Division, GCA Corporation, General Electric Company, General Motors Corporation, GenRad, Incorporated, IBM, Keithley Instruments, Incorporated, NCR Corporation, Polaroid Corporation, Raytheon Company, Sipex Corporation and Teradyne Incorporated.

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 people involved include 16 faculty, 46 research staff, 147 graduate students, 33 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 Electronics 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 1987-88 academic year, 10 PhD, 22 SM, and 20 SB degrees were awarded in conjunction with this research. Research in MTL may be grouped into eleven categories: (1) Integrated Circuits includes analog and digital integrated circuits design as well as advanced process development for "mixed analog/digital signal" IC applications. (2) Integrated Sensors includes technologies for micromachining, design of microsensors and microactuators, and the application of these devices to physical and chemical measurements. (3) Power Devices and Circuits includes several projects supporting broader research at MIT in very high frequency power converters, while other projects are directed toward power device performance and novel fabrication procedures for energy storage devices. (4) Electronic Devices includes devices operating in the semi-classical regime. (5) Quantum Effect Electronics includes novel device structures designed specifically to study and explore quantum mechanical effects arising from carrier interactions with features of sub-100 nm dimensions. (6) Submicron and Nanometer Structures includes some "nanofabrication" projects that are not directly related to electronic devices. The Submicron Structures Laboratory develops techniques for fabricating surface structures with feature sizes in the range of nanometers to micrometers, and uses these structures in a variety of research projects. (7) Process and Device Modeling and Simulation, an actively developing area, uses numerical techniques to solve complex problems of carrier transport and device operation as well as physical problems that arise during materials and device processing. (8) Fabrication Technology covers a broad area of processing and device fabrication with two main themes: novel processes for integrated circuit and device fabrication in silicon and compound semiconductors, and fundamentals underlying materials processing effects. (9) Computer-Aided Fabrication includes computer-based modeling and simulation of fabrication processes design and execution in a realistic fabrication environment. (10) Materials, with the common theme of growth and characterization of thin films for electronic applications, includes research on novel silicon epitaxy, the formation of heterostructures in compound semiconductors, polyimides in microelectronics, and the study and control of the crystalline structure of thin films on amorphous substrates. (11) Packaging includes advanced chip assembly and study of passivating properties of different materials in thin film form.

FACULTY

Several faculty members were granted permanent tenure this year: Associate Professors Robert C. Berwick, Charles E. Leiserson, Silvio Micali, Charles G. Sodini, and George C. Verghese.

Faculty promotions this year include Assistant Professors James G. Fujimoto, William E. L. Grimson, Hae-Seung Lee, Martin F. Schlecht, and William E. Wehl to Associate Professor; and Associate Professors Arvind, John V. Gutttag, and L. Rafael Reif to Professor.

We also welcomed several new faculty members this year. Anant Agarwal, Assistant Professor of Computer Science, recently completed a PhD at Stanford University. Munther A. Dahleh received a PhD at Rice University and is now Assistant Professor of Electrical Engineering. Following two years as Research Engineer at Japan's Nippon Telegraph and Telephone, Jesus A. del Alamo is now Assistant Professor of Electrical Engineering and was also named a Vinton Hayes Fellow. Martha L. Gray, formerly a Research Associate at the State University of New York in Stony Brook, is now J. W. Kieckhefer Assistant Professor of Electrical and Medical Engineering. Leslie A. Kolodziejcki, Assistant Professor of Electrical Engineering, was Assistant Professor at Purdue University. Jacob K. White, formerly at IBM's T. J. Watson Research Center, was named Analog Devices Career Development Assistant Professor of Electrical Engineering.

Faculty members received a number of honors and awards this year:

Professor Jonathan Allen received the Technical Achievement Award from the IEEE Acoustics, Speech and Signal Processing Society for his long-standing contributions to the field of text-to-speech synthesis and computer architectures for digital signal processing.

Associate Professor Robert C. Berwick was the recipient of a John Simon Guggenheim Memorial Fellowship Award, a highly prestigious award given to men and women of high intellectual and personal qualifications who have demonstrated unusually distinguished achievement in the past and who show exceptional promise for future accomplishment.

Institute Professor Emeritus Harold E. Edgerton received the National Geographic Centennial Award in recognition of his distinguished contributions to the field of engineering.

Associate Professor David K. Gifford was honored with the Department's Graduate Student Council Teaching Award.

Hae-Seung Lee, Joseph F. and Nancy P. Keithley Career Development Assistant Professor, and Jacob K. White, Analog Devices Career Development Assistant Professor, received Presidential Young Investigator Awards which fund research by faculty near the beginning of their careers and help universities attract promising PhDs who might otherwise pursue non-teaching careers.

Barbara Liskov, Nippon Electric Company Professor, Professor Sanjoy Mitter and Professor Ronald R. Parker were elected to the National Academy of Engineering.

Marvin L. Minsky, Donner Professor of Science, was awarded an honorary LHD degree by Pine Manor College. He was cited for his pioneering work in artificial intelligence.

Professor Alan V. Oppenheim received the IEEE Education Medal in recognition of his leadership in engineering education through teaching, textbooks, and video tape series in digital signal processing.

The IEEE Aerospace and Electronic Systems Society selected Ford Professor William M. Siebert as the recipient of its Pioneer Award, citing his achievements in the development of pulse-compression radar.

The Department hosted several visiting faculty this year:

Jean-Loup Delcroix, Directeur Général of the Ecole Supérieure d'Electricité in France, returned as Visiting Professor of Electrical Engineering. He spent a month teaching a plasma physics subject and finishing a text on plasma physics with Professor Abraham Bers.

Visiting Associate Professor of Electrical Engineering Marija Ilic came from the University of Illinois to teach and conduct research with Professor Fred C. Schweppe in the area of power system modeling and the design of algorithms for the control of power systems.

Jacob Katzenelson, Visiting Professor of Computer Science, is the Joseph and Sadie Riesman Professor of Electrical Engineering at the Technion in Israel. He taught and conducted research with Professor Gerald J. Sussman on computer-aided design tools for electrical engineering.

From the Georgia Institute of Technology, Visiting Associate Professor of Computer Science Janet L. Kolodner taught a graduate seminar and conducted research with Associate Professor Peter Szolovits on case-based reasoning as it is applied to medical decision making.

Rosemary L. Smith, from the Centre Suisse d'Electronique et de Microtechnique in Switzerland, continued her research with Professor Stephen D. Senturia on integrated circuit technology.

A number of faculty were away this year:

Associate Professor Harold Abelson spent the fall term on sabbatical in Berkeley conducting research at the University of California. Associate Professor Robert Berwick finished a two-volume text on computational linguistics while on leave for the spring term as a Guggenheim Fellow. On sabbatical for the academic year, Associate Professor Lance Glasser studied ultra-high performance superconducting computers at Hitachi's Central Research Laboratory in Japan. Professor Alan Grodzinsky, on sabbatical for the spring term, conducted research on connective tissue and finished a text for the subject, 6.561. Assistant Professor Thomas Knight was on leave for the academic year, continuing his work on architectures at Symbolics Corporation. Associate Professor Charles Leiserson spent spring term on leave at Thinking Machines Corporation gaining practical experience in parallel computer design. On sabbatical for the spring term, Professor Sanjoy Mitter pursued new research in intelligent control. Associate Professor L. Rafael Reif explored current research during his spring term sabbatical in Europe, Japan and Israel. On leave for the academic year, Professor Campbell Searle conducted research on auditory perception. On sabbatical for the academic year, Professor Alan Willsky was in Europe tying together his recent research results and planning future work. Professor John Wyatt was on sabbatical for the spring term working on a nonlinear systems text at the University of California at Berkeley, and working on VLSI research at the California Institute of Technology.

Books published by faculty this year include Advanced Research in VLSI: Proceedings of the 5th MIT Conference edited by Professor Jonathan Allen and F. Thomson Leighton, published by MIT Press; AI in the 1980s and Beyond: An MIT Survey by Assistant Professor Eric Grimson and Assistant Professor Ramesh S. Patil, published by MIT Press; and Theory of Holors by Associate Professor Emeritus Parry Moon and Domina Eberle Spencer, published by Cambridge University Press.

Professors Thomas H. Lee, Jerome Y. Lettvin and Joseph Weizenbaum retired from the faculty this year. Each will continue to serve the Department as Senior Lecturer.

Assistant Professor Roger T. Howe has joined the faculty in the Department of Electrical Engineering at the University of California, Berkeley.

The Department was saddened by the death of Associate Professor Emeritus Parry Moon, who died this year at age 90. Professor Moon joined the Department in 1924 and was awarded the SM degree in 1927. A prolific author, his first book on illuminating engineering was published in 1936. In 1942 he began collaborating in research and writing with Domina Spencer, who he later married, and together they published hundreds of papers and many books. They were awarded the Gold Medal of the Illuminating Engineering Society of America in 1973. Their last book, Theory of Holors, was published by Cambridge University Press in 1986. Even up to the first day of his last hospitalization Professor Moon remained deeply involved in current research and regularly came to his office at MIT.

JOEL MOSES

Department of Materials Science and Engineering

SUMMARY

This has been a remarkable year for our field and for our Department. Announcements of new materials seem to come forth almost daily, especially in such areas as composites, optical materials, and superconductivity. The field of materials is now widely recognized by developed countries as one of three prime technologies for the future, the other two being biotechnology and information technology.

Materials synthesis and processing, an area of this Department which is strong and growing, is a key factor in industrial productivity and international competitiveness. A national study on Materials Science and Engineering now in progress is expected to have as one of its major conclusions that "A national weakness exists in synthesis/processing... with respect to new materials, to manufacturing technology, and to education in Materials Science and Engineering."

Within our Department, our undergraduate numbers remain strong and our graduate program, already comprising exceptional students, continues to become more selective as applications increase, while we purposely reduce slightly the total number of our graduate students. Our curriculum revisions continue, with their major focus to develop broad, generic materials science and engineering subjects.

One new faculty member joined our ranks as an assistant professor this academic year. She is Peggy Cebe, whose research centers on polymeric materials. In addition, our academic program has been strengthened by Visiting and Adjunct Professors as noted later in this report.

The Department has two new endowed professorships, with the completion of the fund raising for the Morris Cohen Chair, and the formation of the POSCO Professorship of Materials Science and Engineering. In addition, 8 of our 10 junior (untenured) professors now have named chairs to help them in their career development.

In this Centennial Year, three important new endowed funds were established through the generosity of alumni. These are the: 1) Anthony D. Kurtz Fund for American Competitiveness in Materials; 2) Ronald A. Kurtz Graduate Fellowship in MSE and Management; and 3) Richard P. Simmons Research Fund in Materials Processing and Manufacturing. Over time, grants such as the foregoing will make a qualitative difference in the lives of our students and faculty members, and in their effectiveness at MIT.

Our Centennial, celebrated June 1-3, 1988, was an unqualified success, with over 350 in attendance. We were pleased to observe firsthand the intense loyalty and warmth so many of our graduates feel for each other, this Department, and this Institute.

THE UNDERGRADUATE PROGRAM

The past academic year was a full one in terms of events affecting our undergraduate program. During the fall semester, the Undergraduate Committee conducted an intensive review of each of the seven generic materials core subjects that make up the heart of our undergraduate program. Results of these discussions were reviewed and further discussed by the Departmental Policy Committee in November and early December. Finally, at the end of the semester, an off-campus, day-long meeting of the entire faculty was held, at which recommendations of the Undergraduate Committee and the Policy Committee were discussed, debated, and voted upon.

The outcome of the above intensive committee work has been a redefinition and updating of the undergraduate "core." A new level of agreement has been reached by the faculty concerning the generic teaching of processing, structure, properties, and performance of real materials in terms of scientific and engineering fundamentals. Changes agreed upon are now being incorporated into the curriculum by the faculty members in charge of the courses.

In the months following the annual Departmental review, the faculty turned its attention to the sequence of "restricted elective" subjects which follow the core curriculum, and in which are taught more specialized topics related to specific materials. It is the sense of the Department that some consolidation of these subjects could lead to an increased flexibility of choice for the students, without compromising the academic rigor and thoroughness exhibited by the present subjects. The planning for this consolidated program is well along, and will be a major topic of discussion in the coming academic year.

The Undergraduate Program is managed by the Undergraduate Committee. Faculty members of this Committee also serve as Departmental student advisors. The Committee also includes student members. This Committee has been very effective in assessing needs for change within the Undergraduate Program, and developing choices for possible policy change. In matters which require more focus than such a diverse committee can offer, recommendations of the Undergraduate Committee are considered by smaller committees composed of senior Departmental faculty. These include committees for faculty teaching assignments, for assignments and policy decisions concerning teaching assistants, and the Departmental Policy Committee which provides an overall strategy for development.

While the undergraduate enrollment in this Department is high by historic standards (approximately 45 per class), we continue to carry out recruiting efforts aimed at maintaining or slightly increasing class size. These efforts included a three-day Open House, direct mailings to the Freshman Class, and subjects and seminars developed specifically to introduce freshmen to Materials Science and Engineering. The undergraduates in the Department are an eclectic group, with broad interests spanning the full range of Departmental activities. They include a large number of women 50 percent, which places us within one percentage point of the two leading departments in this respect (Chemistry and Architecture). Approximately 70 percent of our students are now in our IIIB (Co-op) program. This program involves over 25 industrial and government laboratories. The summer assignments cover the spectrum of materials, with the largest number of students last year being assigned projects in electronic materials.

GRADUATE ADMISSIONS AND THE GRADUATE PROGRAM

Our graduate student population as of mid-year was 223, down from 277 students at our all-time high in the fall of 1985. This reduction was accomplished in spite of an increased total number of applicants. In 1985, 61 percent of those submitting final applications were admitted; in 1987 only 33 percent were admitted. This year the percentage of admissions has dropped again, to 21 percent of the applicants. The overall quality of our applicants remained high and so, with our increased selectivity, we have continued to increase the quality of our graduate student body. We compete, in the admissions process, with the best of other materials departments, and with some other applied physics and other engineering departments as well. Of those applicants we admitted this year, 55 percent chose us, a percentage of which we can be proud. Nonetheless, it is clear that further upgrading of our graduate student body could best come about from increasing this percentage of acceptances. To do so will require that we obtain more and better fellowship support, especially for first year students--since a number of the best students we lost received significantly better first year support than we were able to give them.

Nearly 30 percent of our graduate students are women. Last year, 9 of 44 doctoral degrees awarded were earned by women students. This is an all-time high. International students comprised about 37 percent of the graduate student body. We have continued this year our special mailings to black colleges and universities, with a recruiting pamphlet to aid in these minority recruiting efforts. Three minority students applied and all three were admitted. One of these accepted and will join us in the fall.

The distribution of our students among our six graduate degree programs as of February 1988 was:

<u>Degree Program</u>	<u>Percent of Total Graduate Students</u>
Ceramics	17%
Electronic Materials	24%
Materials Engineering	16%
Materials Science	9%
Metallurgy	25%
Polymers	9%

At the present time, the Department has a doctoral qualification procedure that does not involve a separate examination. Attainment of the doctorate requires that the student pass a General Examination that comprises two parts, a written portion and an oral portion. They may be taken in either order, so long as they are taken within six months of each other. At the present time, six written examinations are given, one for each of the six different degree programs.

There is considerable overlap among the questions given in each of the above six written examinations. But it is the general consensus of the Graduate Committee, that this overlap should, over time, increase. Much discussion was spent in the Graduate Committee on this issue during the last year. A particular proposal discussed in detail was to have the morning portion of the written exam be fully common to all the entire Department. This morning portion would cover the basic elements of materials science and engineering at the level of a solid undergraduate education, with the addition of a graduate level understanding of thermodynamics and kinetics of materials and materials processing. Questions involving synthesis of this subject matter from the undergraduate and graduate curriculum would be emphasized.

Much discussion was held in the Graduate Committee on development of new generic graduate level materials subjects. Discussion focused on a subject on mechanical behavior, and another on processing. The two subjects are now being more fully developed by two faculty members and both will be taught in the coming academic year.

During the last academic year, MIT announced a unique two-year fellows program offered jointly by the School of Management and the School of Engineering. The program is "Leaders for Manufacturing." Its curriculum is designed to educate a new generation of manufacturing leaders. It is a two-year program, leading to two masters degrees, one in management and one in an engineering discipline. Co-Directors of the program are Professor H. Kent Bowen of this department and Professor Thomas L. Magnanti from the Sloan School. The program is being developed and operated in close liaison with a select group of major manufacturing firms.

Through Professor Bowen, and through a number of other faculty and students in this Department, the Department of Materials Science and Engineering has played a strong role in the formation of the program and will play a strong role in its conduct. The first class of students has now been admitted, six of whom will obtain their engineering degree in this Department. The strength of this Department in materials processing provides a natural focal point for our interaction with this new and important educational 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, including the newly established "Morris Cohen Professorship of Materials Science and Engineering," which has yet to be filled. The remaining six endowed chairholders and 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; W. David Kingery, Kyocera Professor of Ceramics; R. Erik Spjut, John Chipman Assistant Professor of Chemical Process Metallurgy; and Bernhardt J. Wuensch, TDK Professor of Materials Science and Engineering.

Term chairs, especially those held by junior faculty members, are of immense value to these faculty members in building their careers. Chairholders and chairs for the coming academic year are: Ronald G. Ballinger, Carl Richard Soderberg Professor; Stuart B. Brown, Richard P. Simmons Assistant Professor of Materials Manufacturing; Michael J. Cima, Norton Assistant Professor of Ceramics Processing; Yet-Ming Chiang, Mitsui Assistant Professor of Contemporary Technology; Andreas Mortensen, ALCOA Assistant Professor of Mechanical Metallurgy; Michael F. Rubner, IBM Assistant Professor of Polymer Physics; Nicole Herbots, IBM Assistant Professor of Electronic Materials; David A. Rudman, Pirelli Associate Professor of Electronic Materials.

THE DEPARTMENTAL CENTENNIAL

Although metallurgical subjects have been taught at MIT ever since its founding in 1865, the first department at the Institute to bear the name of Metallurgy was designated the Department of Mining and Metallurgy in 1888. Accordingly, we celebrated the 100th Anniversary of our Department during the last academic year, with special events on June 1, 2, and 3. The Centennial Celebration was arranged under the auspices of a committee headed by Professor Morris Cohen.

On June 1, the Department held a buffet luncheon and an Open House during which time laboratory tours were conducted and small lectures and demonstrations held to provide an overview of current Departmental activities. That evening, the Centennial Banquet, with over 350 in attendance, was held at the Boston Museum of Science. Banquet participants first had a private showing of the "Ramesses the Great" exhibit. Following dinner and cocktails, formal greetings were received from alumni, students, and foreign guests. Professor Ronald M. Latanision showed slides illustrating the history of the departmental laboratories and Mr. Brian Liebowitz showed slides illustrating MIT "pranks," including some that required considerable expertise in dealing with materials. Additions to the Departmental endowment, described earlier in this report and totaling some \$4 million, were announced. These included the initiation of the POSCO Professorship and completion of the fund raising of the Morris Cohen Professorship, as well as initiation of the special funds described earlier. Dean Wilson concluded the banquet with comments concerning future directions in engineering education at MIT.

On June 2, the Department held a series of lectures dealing with the development of our field, and of our Department. Professor Robert Cahn and Professor Cyril Smith began the program with a historical overview of the field. Professor Bever continued this theme with a detailed discussion of the history of what is now the Department of Materials Science and Engineering at MIT. (In connection with the Centennial, Professor Bever earlier this year completed his history "Metallurgy and Materials Science and Engineering at MIT: 1865-1988." These books were made available to all attendees of the Centennial.) Professor Flemings concluded the morning program with a look to the future of Course III.

In the afternoon, distinguished alumni who have had much to do with the advancement of materials science and engineering in industry spoke on advances in materials science and engineering within their company and industry. These individuals were Dr. Gordon E. Forward, '66, President and CEO Chapparral Steel Company; Dr. Peter R. Bridenbaugh, '68, Vice President - R&D, Aluminum Company of America; and Dr. Praveen Chaudhari, '66, Vice President - Science, IBM Corporation.

On the evening of June 2, the Departmental alumni joined with the all-Institute alumni at the traditional "MIT Night at the Pops." On the following day, June 3, the traditional MIT Technology Day was this year held on "Materials, Productivity, and National Well-Being" and comprised the third day of our Centennial. President Paul Gray introduced the day and Professor Flemings chaired the session. Speakers were Dr. Morris Tanenbaum, Vice Chairman, AT&T; Lester C. Thurow, Dean, Sloan School of Management, MIT; Richard P. Simmons, '53, Chairman and CEO, Allegheny Ludlum Corporation; Richard F. Polich, '65, President, Tallix Art Foundry. The session was attended by a near-capacity audience in Kresge Auditorium and dealt, as the title of the session indicates, with the excitement and opportunities that exist today at the interfaces between materials science and engineering, and societal and human well-being. The session was an outstanding capstone to a delightful and impressive three-day meeting.

FACULTY

Peggy Cebe joined our faculty ranks during this year as a new assistant professor. Professor Gregory J. Yurek was promoted to Full Professor, and Professor Carl V. Thompson was promoted to Associate Professor with tenure. Professors Yet-Ming Chiang, David Rudman and Michael F. Rubner were promoted to Associate Professor.

Professor Robert W. Balluffi was awarded the Acta Metallurgica Gold Medal, an outstanding international award in recognition of ability and leadership in materials research. Professor Stuart B. Brown was awarded the Richard P. Simmons Assistant Professorship of Materials Manufacturing.

Professor Peggy Cebe was the fourth recipient of the J. H. and E. V. Wade Award, which was established to fund innovative research by junior faculty. Professor Yet-Ming Chiang received an Office of Naval Research Young Investigator Award which will provide him substantial funding over the next five years; it is an award he holds in addition to his Mitsui Career Development Professorship. Professor Michael J. Cima was appointed Norton Assistant Professor of Ceramics. Professor Joel P. Clark was appointed POSCO Professor of Materials Science and Engineering. This new chair was made possible by a gift of \$1.5 million from Pohang Iron and Steel Company, Ltd. (POSCO) of Seoul, Korea. Professor Morris Cohen received the prestigious Albert Easton White Distinguished Teacher Award of ASM International and the internationally coveted Kyoto Prize in Advanced Technology.

Professor Thomas W. Eagar was Henry Krumb Lecturer, and received a National Science Foundation Creativity Extension Award for his outstanding work in joining. He also received an Energy Grant from the Japan Endowment Fund for his work on collaboration between the MIT Materials Processing Center and the Welding Research Institute of Osaka University.

Professor Linn W. Hobbs was elected president of the Electron Microscopy Society of America and Professor Latanision became president-elect of Alpha Sigma Mu. Professor Heather N. Lechtman was elected to the American Academy of Arts and Sciences. Professor Rudman was awarded the Pirelli Career Development Professorship to support his teaching and research in superconductivity. Professor Donald Sadoway once again received the MIT Graduate Student Council Teaching Award for Best Departmental Teacher.

Professor Bernhardt J. Wuensch was appointed director of the Center for Materials Science and Engineering, replacing Professor David Litster of the Department of Physics in this important post. Professor Ionnas V. Yannas received the Doolittle Award of the American Chemical Society. Dr. Robert C. O'Handley was appointed by the Chinese Academy of Sciences to the Academic Committee at the Magnetism Laboratory of the Institute of Physics.

The Department's teaching and research activities were much strengthened during the past year by the appointment or reappointment of a number of visiting and adjunct faculty. Professor Lionel C. Kimerling of AT&T Bell Labs continued as Adjunct Professor to teach his graduate course in Compound Semiconductors. Dr. Robert A. Laudise, also of AT&T Bell Labs, joined our faculty as Adjunct Professor, and is actively participating in a number of research programs, including a broad program on processing techniques for high temperature superconductors. Visiting Professor Harold D. Brody taught a graduate course on solidification principles, is participating in material processing research activities, and will continue to do some lecturing as well. Visiting Professor and senior lecturer David V. Ragone taught a freshman seminar last year, will enter our teaching program to greater extent next year, and is actively involved in Departmental research activities, with emphasis in the systems area with Professor Clark.

STUDENTS

The Student Undergraduate Materials Society (SUMS), continued its calendar of activities. They conducted mid- and final term subject evaluations, planned socials, and conducted tours in conjunction with the Centennial. SUMS officers during the fall semester were: Lisa Gassaway (President), Livia Racz (Vice President), Andreas Judas (Treasurer), Anna Napolitano (Secretary), Paohua Kuo (Academic Chair), and Elliot Schwartz (Social Committee Chair). New officers, elected in Spring 1988, are: Livia Racz (President), Jamie Wong (Vice President), Elliot Schwartz (Treasurer), Ken Battige (Secretary), Shahrnaz Motakef (Academic Chair), and Cindy Shen (Social Committee Chair). SUMS has received a grant from United Technologies Corporation to remodel the undergraduate lounge and dedicate it in the memory of Louise Sedlacek '87, a graduate of the Department who died in April. They plan, as well, to seek further contributions from students and others.

Michael S. Mendolia, Jr. and Elliot P. Douglas were elected to Phi Beta Kappa. Daniel J. Kinzie won the "Best Senior Thesis Award." Andre McFayden won an International Precious Metals Institute Student Award for summer co-op work. Junior Steven J. Duncan received a National Consortium for Graduate Degrees for Minorities in Engineering (GEM) fellowship. Edward Kim, a junior, received MIT's Harold J. Pettegrove Award for service to intramural athletics. Julie Brown won MIT's sports award given to seniors who have shown the highest qualities of humility, leadership,

and inspiration in intercollegiate sports for her four years lettering on MIT's Women's Volleyball and Softball Teams, two years lettering on MIT's Women's Basketball Team, co-captaining the Softball Team for the past two years, and captaining the Volleyball Team in 1987.

Students elected to Tau Beta Pi are: Shiao-Ming Chu, Michael R. Groleau, Andre A. McFayden, David J. Miller, Annabel S. Nickles, James D. Powers, Livia M. Racz (all Class of '89); and Gillian L. Brown, David P. Brunco, Elliot P. Douglas, Helen N. Han, Michael W. Russell, Julie A. Tsai, Joyce Y. Wong, Evangeline M. E. Yeo (all Class of '88).

Newly elected officers of the Graduate Materials Council (GMC) are: Jackie Isaacs (Chair and DCGS), Mary Matthiesen (Vice Chair), Scott Sikorski (Secretary-Treasurer and GSC), Elizabeth Holm and Ralph Mason (Social Chairs), Mike Warwick (DCGS and GSC), Nancy Frier (Lunch Seminar Chair), and Richard Higgins (Athletic Chair). GMC continued its seminars and monthly socials, including a summer picnic. They ran a photo contest to obtain suitable materials-related photos for the walls of the Chipman Room. Graduate course evaluations sponsored by the GMC are being used in the discussions on how to change the General Exam and course content such that less time need be spent on graduate degrees. Mansoor Khan won the Materials Research Society Excellence in Research Award. Patricia A. Cullen and Manuel P. Oliveria II received the John Wulff Award for Excellence in Teaching. T. D. Burleigh won the 1988 A. B. Campbell Award from the NACE. Gwendolyn Sturdy won the Celanese Award for Excellence in Polymer Research. Hyoung-June Kim won the Materials Research Society Student Award. Gyeong Man Choi was appointed Assistant Professor at Pohang University in Korea. Kathryn Ann Dannemann and Keith Chiec Chao Hong received the Celanese Awards to recognize excellence in graduate academics, research, or both.

The fledgling MIT Student Chapter of the Materials Research Society elected officers: Sergio Ajuria (Chair), Ann Westerheim (Secretary), and Jerry Floro (Treasurer). The group has organized a series of talks on Materials Research in Industry, with speakers discussing opportunities in materials research at their respective companies. A practice session will be held to prepare students and faculty presenting papers at the November MRS meeting in Boston. A party for students going to the MRS meeting is also being planned.

Fellowship awards for one or more semesters were held during academic year 1987-88 by 29 students. These were: Sergio Ajuria, Bell Labs; Meredith Aronson, MPC; Ketayun Barmak, Bell Labs; Bruce Carvalho, Exxon; Raymond Chiu, MPC; Seng-Shiu Chung, IBM; Patricia Cullen, IBM; Jeffrey Dieffenbach, Rockwell; Kimberley Elcess, Xerox; Sharon Furcone, NSF; Brett Giles, W. J. Brundred Charitable Fund; Sossina Haile, Bell Labs; Susan Hartfield, GM; Olof Hellman, IBM; Richard Higgins, ONR; Elizabeth Holm, NSF; Alan Huelsman, IBM; Jeri Ann Ikeda, ONR; Alan Litsky, Hertz; Mary Matthiesen, Bell Labs; Robin Michnick, MPC; Tresa Pollock, IBM; Heather Shapiro, Hertz; Marlene Spears, Kodak; Ann Westerheim, IBM; and Lock See Yu, MPC.

FACULTY RESEARCH ACTIVITIES

During the past year, Professor Samuel M. Allen completed a successful sabbatical in the Research Laboratory of Nippon Steel Company, working on advanced intermetallic compounds. Professor Averbach extended his work on new materials for magnetic information storage. Professor Balluffi's research continued to gain in international prominence. During the year he made the first direct observations of reversible grain boundary transitions by transmission electron microscopy, and made the first measurements of absolute x-ray diffraction structure factors from grain boundaries. Professor Bever completed his outstanding volume on the history of materials science and engineering at MIT and continued his research and editorial activities in connection with substitution and recycling.

Professor Stuart Brown, in his first year at MIT, began new programs on constitutive behavior of materials in processing, and in the broader area of manufacturing. Professor Cebe is initiating work on structure-property relations of polymeric materials. Professor Yet-Ming Chiang and his students clarified new effects of microstructure and grain boundary segregation on critical current density in high temperature conductors, and developed a novel process for the synthesis of superconducting films from chemical precursors.

Professor Clark expanded the scope of the work in his Material Systems Laboratory to include analysis of electronic material markets from a technical and economic point of view. Professor Cohen continued his work on innovative processing of steel, in

collaboration with G. B. Olson. Professor Eagar continued his work on welding of sheet steels for automobiles and showed that electrode life can be doubled through process optimization. With co-workers Khan and Allemand, he has developed a new, highly accurate, 32-channel optical pyrometer. In another project he achieved promising results in his development of a beryllium-free copper alloy which can be age-hardened. Professor Eagar leads a collaborative effort between the Materials Processing Center and the Welding Research Institute of Osaka University.

Professor John F. Elliot, with a Task Force of the American Iron and Steel Institute, is working on an innovative smelting method that employs a liquid iron bath for the production of steel. He and his associates initiated a program on the functioning of respirable inorganic particles as collectors of mutagenic organic species in combustion systems. Professor Flemings initiated a new program on directional solidification of high temperature superconductors. In other work, real time measurements made on solidification of undercooled alloys showed the formation of metastable phases, and of remelting during recalescence. Work with Dr. James A. Cornie and Professor Mortensen modeled flow and solidification behavior in infiltration of metal matrix composites.

Professor Harry C. Gatos discovered a new form of GaAs which can be converted from semi-conducting to semi-insulating by thermal annealing in the vicinity of 800°C. The material provides the possibility of fabricating devices at room temperature while it is semi-conducting and converting it to semi-insulating for isolation purposes by thermal treatment. This work was conducted in collaboration with J. Lagowski. Professor Nicholas J. Grant continued his work on liquid dynamic compaction for producing plate, sheet, strip and preforms. He has obtained a very fine grain structure in these materials with excellent properties.

Professor Nicole Herbots, during the last year, demonstrated the growth of metallic germanium oxide by ion beam processing, developed a microscopic model for ion beam induced epitaxy, and devoted much time and effort to the development and acquisition of a major piece of equipment to combine molecular beam epitaxy and ion beam deposition.

Professor Linn Hobbs, with Dr. Carol S. Mariani, developed a new mathematical language for describing the structure of glassy networks; he has also established a dedicated crystal precision x-ray diffractometer capability. Professor Keith H. Johnson has continued his theoretical studies on superconductivity and high temperature superconductivity. Professor Gretchen Kalonji has continued her programs on rapid solidification, and on atomistic computer simulation techniques to study interfacial phenomenon. Major emphasis of Professor Latanision's work during the last year has been on the chemical stability of advanced materials: metastable alloys, aluminides, and metal-matrix composites.

Professor Lechtman received a major three-year grant from the J. Paul Getty Trust grant program for her work on "Style in Art and Technology: Pre-Columbian America and Pre-colonial Africa." Professor Koichi Masubuchi continued his work on welding fabrication of marine and aerospace structures.

Professor Mortensen continued his development of a fundamental program on the physical metallurgy and processing of metal matrix composites. He developed and successfully correlated with experiment the first comprehensive model of kinetics of the infiltration process taking account of solidification occurring during flow.

Professor Frederick McGarry showed that thin films of elastomer, coated on reinforcing glass or graphite fibers, produced improved resistance to impact damage in advanced composite laminates. Professor Walter S. Owen published the first results of his work on strengthening mechanisms in nitrogen strengthened, stable austenitic stainless alloys, and developed a new understanding of the magnetic interactions with moving dislocations in ferromagnetic austenites.

Professor Regis M. N. Pelloux's work involved detailed studies of the interaction between the microstructure of advanced alloys and the micromechanisms of fatigue crack initiation and crack propagation. This included single crystals as well as controlled polycrystalline structures. Professor David K. Roylance's research activities included a number of projects on materials engineering of polymers and composite materials. Professor Rubner continued his research aimed at the development of Lagmuir-Blodgett thin film of electrically conductive polymers. He demonstrated, for the first time, that it is possible to fabricate highly anisotropic multi-layer thin films from mixed monolayers containing a surface active component

and a non-surface active based component. Professor Rudman emphasized the fabrication of thin film samples of high temperature superconducting materials, and the characterization of bulk samples. He collaborated with a number of other researchers in this work, within and outside of MIT. Professor Kenneth C. Russell continued to pursue his work on solidification of monotectic alloy composites in a microgravity environment; he studied wetting of non-metallic fibers by metallic melts, and initiated a program on wettability and adhesion of metals on ceramic and polymer circuit substrates.

For Professor Sadoway, the past academic year was marked by the significant discovery that Raman spectroscopy could be used to measure quantitatively the concentration of aluminum oxide in a fluoride melt. This paved the way for the precise measurement of the alumina content of the electrolyte, from which commercial aluminum is extracted. This work was done in collaboration with his graduate student S-Y. Yoon. Professor Julian Szekely continued his work on mathematical modeling aimed at studying a broad range of materials processing operations. He summarized his recent work in a new book, two edited volumes, and a video course.

During the past year Professor Carl V. Thompson and his students developed a single general model that quantitatively accounts for experimental results for the effects of both ion bombardment and dopants on grain growth in silicon. Professor Thompson and his students have also demonstrated the specific relationships between grain size, grain size distribution, and electron migration-induced failure statistics in aluminum interconnects. Professor Harry L. Tuller and his co-researchers demonstrated for the first time a p-n semiconducting transition in the high temperature tetragonal phase of one of the high temperature superconductors. They also succeeded in obtaining quantitative values for structural disorder and oxygen ion mobility in a pyrochlore, and demonstrated a strong correlation between oxygen ion transport and structural disorder in the system.

Early in 1987 Professors Vander Sande and Yurek conceived a new method for processing high temperature superconducting oxides--by oxidation of metallic alloy precursors. This year has seen that concept develop into a proven approach, and a rich area for materials research. Professor August F. Witt, making use of the infrared absorption behavior of free charge carriers in compound semiconductors, showed it was possible to determine quantitatively compositional variations with a spacial resolution of under two microns. Related characterization technology is now being transferred to industry. Through joint sponsorship of DARPA and NASA he established at MIT an advanced semiconductor growth and characterization facility, making it possible to generate bulk semiconductors for device applications.

Professor Wuensch, using large flux grown single crystals of one of the new high temperature superconductors, completed a precise crystal study with the aid of neutron scattering and transmission electron microscopy. He also continued his work on single crystal x-ray scattering analyses of fast-ion conducting chalcogenides. In Professor Yannas' continuing work on artificial skin, independent clinical investigations have shown that the polymeric membrane designed at MIT in 1975 performs at a level equivalent to that of the self graft. Results of his studies of regeneration of rat sciatic nerve by use of copolymer bridges show at least 50 percent recovery of function. Professor Yurek, in work with Professor Vander Sande, outlined above, applied his classical oxidation expertise to the development of new processing approaches for high temperature superconductors.

RESEARCH STAFF

The research staff of the Department of Materials Science and 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 last academic year the Department had 59 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 11 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 seven 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, Robert C. O'Handley, and Gregory B. Olson. Principal Research Associates are James A. Cornie, John F. Mandell and Paul D. Bristowe.

Dr. Bristowe, using a total energy simulated annealing method for determining the equilibrium microscopic properties of crystalline defects mapped out, for the first time using an ab-initio approach, the entire intergranular interaction energy surface for a grain boundary in a semiconductor. Dr. Haggerty made significant progress in modeling laser synthesis of powder formation and of thin film synthesis. Silicon and silicon carbide powders were consolidated into parts exhibiting higher strength than have yet been reported elsewhere. He also successfully made Si_3N_4 insulating films for the first time from laser heated gases. Dr. Lagowski, in work with Professor Gatos described above, has discovered quantitative relationships among various manifestations of an extensively studied defect in gallium arsenide. The discovery sets empirical rules for modeling of the defect.

Dr. Mandell continued his important research in the area of defining the relative contributions of the matrix and the fibrous/matrix interface in controlling crack resistance of polymeric and ceramic based composite materials. Dr. O'Handley, in his magnetic surface characterization facility, put into operation a novel thin-film spin polarimeter and began using it to characterize the magnetic response of amorphous and magneto-optic materials. He fabricated the first quasi-crystals which have a transition metal occupying the icosohedral site. In separate work, he identified a significant difference between magnetic flux expulsion and penetration in high temperature superconductors, by measuring their magnetic relaxation. Dr. Olson continued and brought to a conclusion his research activities on steel processing.

MERTON C. FLEMINGS

Department of Mechanical Engineering

INTRODUCTION AND PERSPECTIVE

The mechanical engineering profession is broadly concerned with energy, motion and materials, and the design, production, and management of systems to meet the needs of society. The profession will have a central role in addressing the challenges of the next decade relating to the supply and efficient utilization of energy, 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 442 undergraduates. The program to control graduate enrollment during the last two years has resulted in a decrease in students to 375 full-time graduate students which is consistent with our plan. The demand for students graduating with SB and SM Degrees has remained 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. Continued upgrading of equipment and instrumentation has occurred in the undergraduate manufacturing and materials laboratories. A new curriculum plan has been developed for undergraduate and graduate programs in manufacturing. During the past year the undergraduate core manufacturing subject has been revised and a new graduate core subject in manufacturing has been developed. Also, a critical review of graduate disciplinary courses has been conducted.

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 in the last year was approximately \$6.5 million, a decrease from the previous year, in which the Department received significant funds in the form of one time equipment grants. Research support from industry has continued to be significant, representing approximately 25 percent of the total research administered through the Department.

During the year faculty in the fluid and thermal sciences area have strengthened research programs in computational fluid mechanics and turbulent reacting flows, heat-transfer augmentation, the thermal-fluid processes controlling growth of electronic materials and fluid mechanics related to biotechnology.

Faculty in the mechanics and materials areas have developed research in high performance metals, fibers and polymeric materials, and continued major programs in geomaterials and biomaterials. Faculty in manufacturing, design, and control have advanced the capabilities in flexible manufacturing and robotics and extended investigations into basic manufacturing processes. Faculty in the biomedical engineering area have continued to make significant progress in developments related to treatment of cancer patients using ultrasound, development of artificial skin and nerve-regeneration, and in understanding the biomechanics of joints and limbs, as well as the basic fluid processes related to diseases of the cardiovascular, pulmonary, and ocular systems.

Effort has continued in the development of the Martin Center for Engineering Design. This facility includes a prototype development laboratory, an interactive classroom, and special seminar rooms for design education and research. During the year, a set of four Macintosh Computers were acquired as part of the educational program in graphic visualization. Additionally, a subject in the coupling of microprocessors and mechanical systems was introduced using the prototype laboratory facilities. The facilities of the center have helped to provide a unique opportunity to exploit computer-aided engineering techniques from concept generation through prototype development in the design curriculum.

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.

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 industrial experience as an integral part of the program.

The Department enrollment continued at levels comparable to the past few years. The new sophomore class of 142 included 35 women and 7 black students. Approximately 20 percent of the class are minorities.

Course II-A provides an alternative to the regular mechanical engineering program and is intended for students who wish to design a special program coupling such areas as biomedical engineering, management, and energy policy with mechanical engineering. Thirty-two students were enrolled in II-A. The Department has been heavily involved in the School of Engineering Internship Program since its inception in 1977-78. This past year, 63 students from the Department are members of the Program: 9 graduate students, 28 seniors and 26 juniors. In 1986-87 the Department awarded 131 SB degrees (114 in Mechanical Engineering, 13 without specification and 4 in Course II-B).

Undergraduate Curriculum

The Department Academic Policy Committee has reviewed the content and cohesiveness of the undergraduate curriculum and has broadly defined the evolutionary development of the undergraduate curriculum in three areas - (1) development of an integrated laboratory sequence starting with an introduction to instrumentation and measurement and leading to computer-aided data acquisition and analysis, (2) an increased coupling of manufacturing and design, and (3) a strengthening of the basic disciplinary subjects with improved computational techniques. During the last year the introductory subject in measurement and instrumentation has been revised and expanded to provide a foundation for all the upper level laboratory subjects. Additionally, the planning for an integration of the design and manufacturing core curriculum has been completed with the revised program to be introduced next year. Additionally, a new facility with interactive graphic workstations has been planned in cooperation with Project Athena for use with thermal-fluid science courses.

Professor James Fay working with faculty from the Humanities School has developed a new context subject, 2.93J Engineers, Scientist, and Public Controversies which was offered this past spring.

Undergraduate Student Organizations

The Student Chapter of the American Society of Mechanical Engineers under the leadership of its officers: Jason Jonas, President; Evelyn Vance - graduate student, Vice-President; Jeff Kholr - graduate student, Treasurer; and Wendy Haller, Secretary; continued to make strong contributions to Department and professional activities with a membership of nearly 139 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 15 students. This past year the organization provided academic support in subject reviews, sponsored corporate presentations and had professional engineers make presentations to its membership. The organization was ably lead by Reginald D. Tucker, President; Robert L. Boone, Vice-President; Kendra Ann Williams, Secretary; and Gregory Markham, 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: Alexandra Page, President; John V. Colombo, Vice-President; Kamala J. Sundaram, Treasurer; and Ginny Loop, Secretary; 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. The chapter officers were: Corinna Fu, Chairman; Barbara Hove, Vice-Chairman; Ethan Foxman (Physics Department), Treasurer; and Andres Villarreal, Secretary.

Undergraduate Student Awards

Many undergraduates in the Department were recognized for academic and athletic excellence, engineering creativity, and community service.

Several students were recipients of the Departmental De Florez Award for outstanding ingenuity and creative judgement. Sandra M. Lippka, won first prize for her "Self-adjusting Variable-height Gangway System" for handicapped passenger access to Boston harbor ferries. Second Prize was awarded to Marc C. Filerman, for his design of a "Mechanical Feeding System for Quadriplegics" while Catherine J. Anderson and James D. Worden, also share second prize for their "Optimized Solar-Racing-Car Wheel-System Design".

Alice D. Haggerty and Vittal K. Vasista won the Departmental AMP award for outstanding performance in course 2.86 Manufacturing Processes Laboratory.

Waldo T. Best, Christian H. Passow, Gregory A. Tashjian, and Kenneth E. Goodson, won the Departmental Robert L. Hallock Tensile Test Award for excellent machining and heat treating of a tensile test specimen.

Charles DiRuzzio, Thomas A. Fuhlbrigge, Krisztina J. Holly, John H. Manthorpe, Rebecca J. Munroe, Antonio A. Pangan and James E. Rubesch won the Departmental Wunsch Foundation Silent Hoist and Crane Company award for outstanding design and fabrication in the Mechanical Engineering area.

Alexandra E. Page won the Mechanical Engineering Department Service Award in recognition of her leadership in student activities.

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 Boyd Bucher, Honor Jones, Jack Kotovsky, and Amy K. Luong.

At the 1987 Institute-Wide Awards Convocation Yvonne M. Grierson received the Betsy Schumacker Award which is presented annually to an undergraduate woman for excellence in athletic competition, while G. Sean Garrett received the Admiral Edward L. Cochrane Award which is presented annually to a male senior who has shown the highest qualities of humility, leadership, and inspiration in intercollegiate athletics. Dianne E. Di Massa was the female recipient of the Malcolm G. Kispert awards which are presented annually to the male and female senior scholar-athletes of the year. Gold awards honoring leadership and service were presented to Sean P. Casey for intramural volleyball management, Martin Scheidl for service as Varsity Club president, Alison Arnold for gymnastics, and Hugh Ekberg for football.

Also at the Awards Convocation, Ellen Lin 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 made 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 Carl R. Peterson, 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 intended as 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 1987 was 375 full-time students. In the fall of 1987 there were 41 women, 7 black, 5 Hispanic, and 13 Asian-American students in the graduate program. In September 1987, 129 new students were admitted from 437 applicants and 62 students registered.

In 1987-88 the Department awarded 143 SM degrees (of which 14 were combined SB/SM degrees), 5 Mechanical Engineer degrees, and 41 doctoral degrees.

The Department Faculty voted in April 1987 to institute a joint SM degree program with the Woods Hole Oceanographic Institute.

In 1987-88, 91 percent of all graduate students received support from the Department, MIT funds, fellowships, the government, or industry. Sixty-nine percent of the graduate students were supported by the Department through research and teaching assistantships.

Graduate Curriculum Development

Three new graduate subjects were introduced by Department faculty to strengthen our programs. Professor Richard Lyon developed the subject 2.066 Machinery Noise and Diagnostics. Professor James Fay developed with Professor Adel Sarofim of Chemical Engineering the subject 2.29J Air Pollution Control. Professor William Durfee developed the subject 2.737 Designing Smart Machines.

Additionally, as a result of the study of the graduate curriculum in the manufacturing area, several new subjects were introduced on a seminar basis including Introduction and Analysis of Manufacturing Processes by Professor Timothy Gutowski, Manufacturing System Analysis by Dr. Stanley Gershwin and Axiomatic Design of Manufacturing Processes and Products by Professor Nam Suh. An overall revision of the manufacturing curriculum has been initiated with the goal of developing a small set of core subjects which will provide a basic foundation in manufacturing.

An overall review of graduate disciplinary subjects in the Department has been conducted to determine those areas in which new developments are needed as well as subjects which should be eliminated or offered on an every other year basis. As a result of the review, several subjects have been consolidated.

Two new textbooks were published during the past year - Internal Combustion Engine Fundamentals written by Professor John Heywood and Machinery Noise and Diagnostics authored by Professor Richard Lyon. Two additional texts are in process at the printers, "Physicochemical Hydrodynamics," authored by Professor Ronald Probstein and "The Principals of Design," authored by Professor Nam Suh.

Graduate Student Awards

J. Steven Brown is the first 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.

Erik G. Vaaler is the first recipient of the Carl G. Sontheimer Prize recognizing innovation in Mechanical Engineering.

Jesper Otterbeck was one of the recipients of the Wunsch Foundation Silent Hoist and Crane Awards for outstanding design and fabrication in the Mechanical Engineering area.

RESEARCH

Support Level and Distribution

The total volume of sponsored research for 1987-88 administered in the Department is \$6.5 million. This is a decrease of \$0.9 million from the previous year, which included a number of large one time equipment grants. Additional sponsored research of an approximately equal amount is administered through interdepartmental laboratories and centers. The Department sources of research support are derived from 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. Approximately half of the faculty are explicitly involved in basic research and almost every research project in the Department has a component of fundamental research. In research applications the fraction of faculty involved in the four major application areas are: manufacturing, materials and mechanics, 35 percent; energy and environment, 45 percent; biomedical engineering, 22 percent; and systems and design, 18 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 axiomatic design 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 been expanded with the addition of 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 wide variety of processes involved in 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 Departments, has been conducted by Professor Michael P. Cleary to evaluate rock fracture related to oil and gas extraction and by Professor Peterson to improving 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 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 and a new experimental program to understand multicomponent flows has been initiated by Professor Harri Kytomaa. Additionally, Professor John H. Lienhard V has initiated research to determine heat and mass transfer in two-phase flow systems.

Research in the Sloan Automotive Laboratory has been undertaken with the support of industrial consortiums to evaluate the uses of ceramic materials in engines and to develop an improved understanding of combustion. 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. Hoult. Also, fundamental studies considering turbulent combustion have been conducted by Professor Tau-Yi Toong.

Several new 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 initiated by Professor Sonin. Professor Ronald F. Probst and Patricia Renaud have conducted research in the control of ground water at hazardous waste sites.

Several faculty are developing fundamental computational and analytical tools. Professor Klaus-Jürgen 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. Professor Triantaphyllos R. Akylas continues to make progress in developing analytical techniques for characterizing wave propagation in fluids and their interaction with surfaces.

Professor Patrick Leehey has conducted basic experimental studies to determine noise generated by fluid flowing past a solid boundary.

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 that culminated in a telemetered hip endoprosthesis providing the first measurements of pressure in the hip joint ever made in a human. Studies conducted in the laboratory by Professor Woodie Flowers have continued the development of a microprocessor-based biofeedback and gait analysis system for above-knee amputees, while effort to develop aids for the handicapped has continued by Dr. Michael Rosen. 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.

Research results obtained by Professor Ioannis Yannas in collaboration with Dr. John F. Burke of Massachusetts General Hospital to evaluate a biocompatible artificial skin for severely burned patients and materials to regenerate nerves have been encouraging.

In the Laboratory for Medical Ultrasonics, Professor Padmakar Lele and his colleagues have continued in patient evaluation in which tumors are treated through controlled hyperthermia using focused ultrasound.

Biomedical research in the fluid mechanics laboratory has shown significant progress in the recent work of Professor Roger B. Kamm in 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, and the Martin Center for Engineering Design.

Professor Thomas B. Sheridan and Dr. Dana R. Yoerger of the Man Machine Systems Laboratory have made significant progress in the development of undersea remote manipulation 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 has developed automatic scaling techniques for mechanical assemblies which allow scaling to be performed on the basis of design and prescribed constraints in objective functions. This research is complemented by effort to develop, using expert systems technology, designer-machine interfaces which enhance the iterative design functions.

The activity in the machine dynamics and control area has continued to grow with efforts of Professors Steven Dubowsky, Richard H. Lyon, and Warren Seering. Professors Dubowsky and Seering have continued efforts to develop analytical and experimental techniques for evaluation of high speed machine performance, while Professor Lyon has further developed techniques for analyzing vibration signatures as a diagnostic tool in rotating machine performance with a detailed application study of diesel engine characteristics.

In transportation technology, 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 performance. Research in the control and dynamic performance of automotive vehicles and in truck/pavement interactions was also conducted by Professor Hedrick.

Research directly related to the process of engineering design has been conducted in the Martin Center by Professor Seering and in the teaching of design by Professor Flowers and Technical Instructor James Grinnell.

FACULTY AND STAFF

Size and Composition

On September 1, 1987 there were 57 active faculty: 28 professors, 17 associate professors (14 with tenure), and 12 assistant professors. Eight faculty are minority group members: a black professor, two women, and five 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. Among the staff are two Asians and one Hispanic. Of the five administrative staff, three are women; and of the 32 support staff there are two black women, one Hispanic, and one Asian. The Department has nine hourly staff, including two black men.

New Faculty and Staff

Two new faculty have been appointed to the Department during the last year.

Dr. Mary Cunningham Boyce joined the Mechanics and Materials Division in July as an Assistant Professor.

Dr. John H. Lienhard V joined the Thermal and Fluid Sciences Division in February as an Assistant Professor.

Faculty Development Funds

Several companies and foundations continue to provide grants of unrestricted funds to the Department and funds to support the career development of young faculty. These discretionary funds have been used as seed funds to initiate new research areas, to enhance the development of young faculty careers, and to acquire equipment for education and research. Several young faculty were supported this year by the DuPont Engineering Grant and the Shell Engineering Grant. These grants have provided significant assistance in initiating research activities by young faculty and the commitment they represent from industry to education is most encouraging.

Notable Accomplishments and Awards

Associate Professor Woodie C. Flowers and Associate Professor Roger Kamm were promoted to full professors effective July 1, 1988.

Associate Professor Ahmed Ghoniem and Associate Professor Anthony T. Patera were granted permanent tenure effective July 1, 1988.

Assistant Professor Ming-Kai Tse was promoted to Associate Professor effective July 1, 1988.

Assistant Professor Mary C. Boyce is the first recipient of the Lynde and Harry Bradley Foundation Career Development Chair. The chair is for two years, effective July 1, 1988.

Assistant Professor John H. Lienhard V has been selected the first holder of the George N. Hatsopoulos Junior Professorship in Thermodynamics. The chair is for two years, effective July 1, 1988. The chair was established in the Department to recognize George N. Hatsopoulos, who was a member of the Department faculty. He also was one of eight recipients from MIT to receive a 1988 Presidential Young Investigator Award.

Assistant Professor Emanuel M. Sachs has been awarded the Rockwell International Career Development Professorship. The chair is for a three year term, effective July 1, 1988.

Assistant Professor Kamal Youcef-Toumi has been selected as one of the recipients of the Carl Richard Soderberg Professorship in Power Engineering. The chair is for two years, effective July 1, 1988.

At the 1987 Institute Awards Convocation, the Graduate Student Council awarded Associate Professor Rohan Abeyaratne a Teaching Award for "exceptional and inspirational teaching".

The 1987-88 Jacob Den Hartog Distinguished Educator Award was presented to Anthony T. Patera.

Professor Nam P. Suh received an LHD from University of Lowell.

Dr. Yukikaza Iwasa received the 1987 Hetenyi Award of the Society for Experimental Mechanics for the most outstanding research paper published in the Journal for Experimental Mechanics in 1986: Dr. Iwasa's paper "High-Resolution Experimental Techniques for Cryomechanics -- A Study of Mechanical Behavior of Materials at 4.2K".

Resignations/Retirements

Professor Tau Yi Toong has retired from the faculty after 40 years in the Department effective June 30, 1988 and will continue his association with the Department as a senior lecturer.

DAVID N. WORMLEY

Department of Nuclear Engineering

The Report to the President provides an occasion to review the Department of Nuclear Engineering's progress during the past year. As is evidenced in the following paragraphs, the department has continued to provide its students with a high standard of education and research in science and engineering relevant to the peaceful applications of nuclear processes.

ACADEMIC PROGRAM

During the academic year 1987-1988, 146 students were enrolled in the nuclear engineering graduate program. Of this number, approximately 25 percent were newly admitted. International students accounted for approximately 38 percent of the graduate population. Interest in our undergraduate program was sustained at last year's level. Next September, we expect to welcome seven students to our sophomore class.

Advanced degrees were awarded to a total of 42 students at the following degree levels: 13 doctorates, 5 nuclear engineers, 23 master of science, and 1 five-year bachelor of science/master of science degree. Six women were among the 42 degree recipients. In addition to the five-year BS/SM degree mentioned above, two students completed requirements for the bachelor of science degree.

As in the past, the Engineering Internship Program continued to be a valuable educational resource for five undergraduates and one graduate student. During the year they interned at EG&G Idaho, Boston Edison, Brookhaven National Laboratory, and General Electric Research and Development.

In the area of curriculum development, the nuclear engineering department (NED) established a committee to investigate means to improve the use of computers in NED courses. The committee members include Professor Nathan Siu, chairman; Professors Michael Driscoll, Jeffrey Freidberg, and Sidney Yip; Rachel Morton, a staff member; and graduate student Andy Dobrzeniecki. They have surveyed faculty and students of the NED, other MIT departments, and nuclear engineering programs of other universities to identify alternatives. The surveys indicated that NED courses should make greater use of computers, and that there are a number of problems with the current process used to make NED computer resources available to students. A number of actions to deal with the latter were identified and will be implemented shortly. Software packages to encourage increasing computer usage in a target set of classes are being developed.

An extensive review of the department's undergraduate program was completed by the undergraduate committee under the chairmanship of Professor John Meyer. Resulting actions included: major changes to our radiological sciences track (such as adopting a quantitative physiology sequence and providing undergraduate versions of three departmental graduate offerings); evolutionary changes to our fission track and our fusion track; and judging acceptability of these actions by use of the goals developed by the School of Engineering.

Dr. John Wesson, a renowned plasma theorist from the JET Laboratory in England, visited the department under the sponsorship of Professor Freidberg for six weeks during the spring semester. While here, Dr. Wesson gave a series of 12 lectures as part of our advanced MHD course 22.616 MHD Theory of Magnetic Fusion Systems II.

RESEARCH

During the fiscal year ending June 30, 1987, 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

The Nuclear Power Plant Innovation Project continues to be a significant project for departmental research. The four principal elements of this study involve 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.

Research in the LWR area has focused on plant performance requirements, conceptual design innovation, and independent technological advances. Professors Michael Golay, Mujid Kazimi, David Lanning, Meyer, Elias Gyftopoulos, and Neil Todreas are involved in this study. Included in this work is an investigation of the safety features of the Small Boiling Water Reactor which is currently under conceptual development by the General Electric Company. This work involves the investigation of passive mechanisms for decay heat removal from within the reactor containments to external heat sink via condensation of steam and natural convection of water around the containment shell. Also involved is the study of a steam injector to circulate the coolant in the system.

The MHTGR project has concentrated its efforts on safety, investment, and licensing goals, incentives for fuel quality improvement, and investigation of a direct-cycle gas turbine combined with the passively safe MHTGR core. Professors Lanning and Lawrence Lidsky continue to guide student research projects on the assessment of the modular high temperature gas-cooled reactor. A recent project involving experimental studies on the deposition and lift-off of fusion products in the MHTGR primary circuit has been initiated. Emphasis this past year has also been on the further assessment of the direct cycle gas turbine concept that has been found to be possible with present-day technology at reasonable costs. Another aspect of this study has shown that recent developments in heat exchanger technology and high power electronics make possible modular reactor designs capable of 50 percent efficiency using only technologies and materials in current use. This somewhat surprising result has led to a substantial revival of interest in this concept. Under the direction of Professors Driscoll and Todreas, research has been carried out on decay heat removal by natural convection to ambient air for the MHTGR.

The institutional and policy analysis portion of the overall project is being investigated by Professor Richard Lester. He continues to focus attention on the sources of international variations in industrial performance in nuclear power plant construction and operation. Studies comparing the effect of safety regulation on plant performance have been completed. Research in the area of international comparison of light-water reactor performance continues under the direction of Professor Kent Hansen.

Professor Hansen continues to coordinate a multi-million dollar, multi-year, Department of Energy (DOE) program involving 12 faculty principal investigators from five engineering school departments. Research areas include: thermal plasmas, fracture mechanics, automated welding, and engineering analysis and design.

Under the direction of Professors Otto Harling and Driscoll, a major project is well underway at the MITR-II to reduce dose rates and stress corrosion in PWR and BWR systems through experimental research employing in-pile loops. Significant funding for this work has been obtained from national, regional, and local utility organizations in the US. Recently, support for a third facility, an in-pile autoclave for irradiation-assisted stress corrosion cracking, has been obtained from the Tokyo Electric Power Company. Professors Ronald Ballinger and Harling are the principal investigators in this new phase of the work.

In the area of nuclear reactor instrumentation and control, Professors Allan Henry, Lanning, and 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. The studies involve both small reactors and a space power system and large LWR cores where multi-dimensional effects must be included. Recent experiments at Sandia National Laboratory utilizing one of the control algorithms for small-reactor control demonstrated a capability to control reactor power over several orders of magnitude on any chosen rate of rise (reactor period) down to e-folding times of 0.5 sec, and to level off at the new power level without significant overshoot. A new project is being initiated on the study of automatic control of multi-modular nuclear reactor power plants.

In the area of reactor physics modelling, Professor Henry and his students have completed a number of efforts. A method for recapturing local fuel pin power from nodal solutions throughout the lifetime of a reactor has been developed and tested successfully against utility experience. A preliminary study has demonstrated the adequacy of the two-group model for analyzing reactor transients. A nodal code for analyzing criticality in graphite cores has been successfully exported to GAT. A supernodal method capable of analyzing LWR operating transients in real time has been developed and tested. Work has continued on the development of a more efficient one-dimensional transient analysis code and on an improved reactivity meter.

Research on the development of the parity simulation approach to problems in neutron kinetics, fluid flow, and neutron diffusion has continued under the supervision of Professors Hansen, Henry, and Meyer. This concept has been successfully applied to neutron kinetics and to single-phase and two-phase fluid flow.

Study in the area of reactor safety, reliability analysis, and risk assessment is conducted by Professors Norman Rasmussen and Siu. A project investigating the propagation of uncertainty associated with plant aging was recently completed under the sponsorship of Brookhaven National Laboratory. This project developed a computer code to perform the uncertainty propagation and to determine the uncertainty importance of the model parameters. An interesting result of this analysis, obtained in the analysis of a particular system, is that the range factor for the system reliability uncertainty for that system remained fairly constant, i.e., that the uncertainty scaling did not change with time.

Two recently completed projects in the reliability analysis area involve analyzing the reliability of systems currently being designed. The first project, supervised by Professors Golay and Siu, investigated the risk associated with advanced small BWR designs. A result of this work is a systematic methodology for identifying risk-significant components and systems which should be incorporated in conceptual plant designs. The second project, supervised by Professor Siu and sponsored by Rockwell International Corporation, developed a methodology for analyzing the reliability of components and subsystems which are being designed and for which no failure experience is available.

Research in the area of post-accident behavior is directed by Professor Kazimi. As part of the Electric Power Research Institute (EPRI) program on severe LWR accidents, he has studied the potential for the containment survivability of a severe accident.

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.

In the area of nuclear materials and radiation effects, Professor Ballinger is continuing to study the effects of environmental and microstructural factors on the cracking susceptibility of Ni-Cr-Fe alloys used in nuclear power systems. Professor Harling is exploring methods of developing improved nuclear structural alloys for the critical fusion reactor first-wall application.

Fusion research continues under the supervision of Professors Freidberg, Ian Hutchinson, Kazimi, Kim Molvig, and Thomas Dupree. Professor Freidberg, Dr. Daniel Cohn, and several students are actively collaborating on problems involving plasma ignition and burn control as applied to the International Thermonuclear Experimental Reactor (ITER) and the Compact Ignition Tokamak (CIT).

Professor Hutchinson has assumed the role of Division Head for the Alcator C-MOD experiment, the major confinement experiment at the PFC. Construction of a new tokamak experiment, Alcator C-MOD, is progressing on schedule. This experiment follows the decommissioning of Alcator C and in many important physics areas (RF heating, impurity control, cross sectional optimization) serves as a prototype for the Compact Ignition Tokamak Project. The CIT experiment is expected to serve as the "flagship" of the US fusion program over the next decade and should produce the first fully ignited D-T plasma.

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. He and his students have established criteria to guide the development of passively safe fusion reactor designs.

The field of radiation includes studies in applied radiation physics, condensed matter science, and radiological science. A new method of extracting the intermicellar structure factor for strongly interacting ionic micelles using a small-angle neutron scattering technique has been developed by Professor Sow-Hsin Chen and his students. He has also been conducting quasielastic light scattering studies of ionic micellar solutions and dense microemulsions. Atomistic simulation studies of problems in materials science and statistical physics are being pursued by Professor Yip and his research assistants.

Professor Gordon Brownell, the principal faculty member in the area of radiological science, and his research group have designed and built a positron tomograph, PCR-I, that is currently undergoing physical and biological testing. A high-resolution cylindrical positron camera is also being developed for the Massachusetts General Hospital. Also, a work station has been established for microscopic imaging in Whitaker College.

Professor Harling's project on boron neutron capture therapy for brain cancer has successfully completed its first year with significant progress on all tasks including the design of an epithermal patient treatment beam. Funds are now being solicited for the construction of the epithermal beam. Student interest in this medical therapy project remains high.

New Research Projects

Professor Siu received a research grant from the USNRC to study improved methods for modeling nuclear power plant accident sequences. This research will center on developing alternatives to the current event tree/fault tree methodology, and should lead to improved integration of plant physical models with risk models.

Dr. Marvin Miller has initiated a new project on the nuclear weapons proliferation implications of the acquisition of nuclear-powered attack submarines by non-nuclear weapon states such as Canada, Brazil, and India. Professor Lanning is also participating in this project, which is sponsored by the MacArthur and Plowshares foundations.

FACULTY ACTIVITIES

The nuclear engineering department faculty have been involved in numerous on-campus activities throughout the year. Because of space limitations, only a brief description of their accomplishments can be listed.

Three faculty offered special courses during the summer of 1987. Professors Rasmussen and Todreas presented their annual two-week special entitled, "Nuclear Power Reactor Safety." This session continues to be well attended by members of the US nuclear industry as well as those of the international community. Professor Henry presented a week-long course on "Modern Nodal Methods for Analyzing Light-Water Reactors." This summer presentation continues to be a very popular offering.

During the academic year 1987-88, the following faculty guided the department and students through the administrative process. Professors Freidberg and Kazimi continued as Graduate Admissions Officer and Graduate Financial Aid Officer, respectively. Professor Driscoll served as Graduate Recruiting Officer, and Professor Henry represented the Department on the Committee on Graduate School Policy (CGSP). 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 chaired the department's undergraduate program review committee. Professor Siu served as the faculty advisor for the ANS Student Chapter; he also coordinated the department's Independent Activities Period (IAP). Professor Ballinger continued to supervise the UROP program and the Engineering Internship Program, and also served as the Undergraduate Financial Aid Officer. The department's Safety Committee and its Computer Committee were chaired by Professor Todreas. Professors Brownell, Freidberg, Gyftopoulos, Lester, and Rasmussen continued to serve as Graduate Registration Officers.

In addition to departmental assignments, our faculty have made significant contributions to both School of Engineering and Institute activities throughout the year. Professor Rasmussen continues to serve as chairman of the MIT Committee on Reactor Safeguard and is a member of the Institute Council on Environmental Health and Safety.

Professor Lester continued his appointment as Executive Director of the MIT Commission on Industrial Productivity. The Commission, consisting of 18 leading social scientists, engineers, and physical scientists on the Institute faculty, has been 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. Professor Lester participated in a presentation of the Commission's interim results at the Annual Meeting of the American Association for the Advancement of Science (AAAS) in Boston last February. He is also a member of the Advisory Committee of the Center for Technology, Policy and Industrial Development.

Professor Gyftopoulos continued his services as Faculty Chairman of the MIT Sustaining Fellows Program, and as chairman of the Interschool Working Group on Context Subjects.

Besides serving as departmental CGSP representative, Professor Henry holds membership on the Institute's Advisory Committee on Shareholder Responsibility. Professor Lidsky serves as chairman of the Institute Committee on Curricula. Professor Yip is a member of the Committee on Student Affairs, and Professor Kim Molvig sits on the Faculty Club Advisory Board.

Two faculty members hold appointment on the Committee on Radiation Exposure to Human Subjects: Professor Todreas, as chairman, and Professor Brownell. Professor Brownell also participated in a special faculty committee, the Harold E. Edgerton Faculty Achievement Award Selection Committee for 1987-88. Professors Todreas and Golay are members of the Committee on Outside Professional Activities.

Professor Harling directs the interdepartmental Nuclear Reactor Laboratory and is a member of the MIT Committee on Reactor Safeguard. Besides Professor Rasmussen, other faculty serving on this committee include Professors Ballinger, Kazimi, and Lanning.

In addition to on-campus activities, nuclear engineering faculty have continued to expand their professional horizon by their involvement in outside professional conferences and speaking engagements. Professor Henry presented a paper at the International Symposium and Workshop on Nuclear Simulation held in Schliersee, West Germany. Professor Siu chaired a session on probabilistic risk assessment at the Ninth International Conference on Structural Mechanics in Reactor Technology, held in Lausanne, Switzerland, in August 1987.

Professors Harling and Driscoll, together with Dr. Gordon Kohse of the Nuclear Reactor Laboratory, presented a paper on MIT's in-pile loop program at the International Conference on Water Chemistry in Nuclear Power Systems held in Japan in April 1988. They also visited a number of laboratories and industrial organizations under a grant awarded by the Japanese government. Professor Harling was also invited to present papers at the Japan Atomic Industrial Forum meeting on reactor water chemistry, at Musashi Institute of Technology and Kyoto University Research Reactor Institute. In March 1988, Professor Gyftopoulos participated in a two-day meeting in Geneva, Switzerland, as a member of a nuclear safety steering committee that structured and organized an international conference on "Energy for Third World Countries" to be sponsored by the World Council of Churches. He was the invited speaker at the May 1988 European Conference on Development of Energy Conservation Technologies, sponsored by the Commission of the European Communities and organized by the American College of Greece in Athens, Greece.

Professor Kazimi participated in a national panel convened by USDOE to study the economic, safety, and environmental prospects of fusion magnetic energy. He was a member of the US delegation to a meeting on the same subject organized by the International Energy Agency in Rome, Italy, in November 1987. He gave invited lectures on this subject at the American Physical Society meeting in San Diego in November 1987 and at the Karlsruhe Nuclear Research Center in March 1988. He also organized and chaired a session on thermal aspects of nuclear reactor severe accidents at the 1987 National Heat Transfer Conference.

Professor Russell's research on spinodal decomposition in Fe-Ni and Fe-Ni-Cr Invar-type alloys has led him to organize an international conference around that topic. The conference is planned for March 1989.

Last October, Professor Lester was an invited lecturer in a series on New Horizons in Science and Engineering at SUNY New Paltz, and this month he was invited to Leningrad where he participated in a Workshop on Energy Programs sponsored by the International Foundation for the Survival and Development of Humanity.

Professor Lanning was invited to present a paper on the MHTGR at the National Science Foundation Workshop on Research Needs of the Next Generation of Nuclear Power Technology, held in October 1987 at Idaho National Engineering Laboratory in Idaho Falls. Also, a seminar on Advanced Instrumentation and Controls was presented at the North Carolina State University for their Department of Nuclear Engineering in January 1988.

Professor Lidsky published several articles in the popular press describing the potential impact of demonstrably safe, modular nuclear power plants on the future of the US electric utility industry. He was invited to discuss this topic at several symposia and at a Congressional subcommittee studying the question of nuclear reactor standardization.

In addition to participation in professional conferences and seminars, department faculty are well represented in professional associations. Professor Rasmussen serves as chairman of the Cabot Corporation LNG Safety Committee. He is a member of the Science Advisory Board for the Cleanup of TMI-2; a member of the Los Alamos National Laboratory N Division Advisory Committee; a member of the Nuclear Safety Review Panel, Republic of China; a member of the safety review committee of Rockwell International for the Rocky Flats facility; and a member of the PRA Review Committee of Savannah River Reactors. In addition, he is a member of the Brookhaven National Laboratory NED Visiting Committee and the Princeton Plasma Physics Laboratory Visiting Committee. He continues to serve on the Board of Directors at Pickard, Lowe and Garrick; and on the Board of Trustees at Northeast Utilities. In May, he concluded a six-year appointment to the National Science Board.

Professor Gyftopoulos was elected vice-chairman of the Board of Trustees of Anatolia College, an American institution in Salonica, Greece. In March, Professor Hansen was elected a Director of Stone & Webster. He is also on the Scientific Advisory Committee to the Idaho National Engineering Laboratory. He continues to serve as a member of the National Research Council's Commission on Engineering and Technical Systems. Professor Kazimi is a member of a DOE panel convened to assess the economic, safety, and environmental aspects of fusion energy utilization in the next century.

Professor Lanning continues to serve on the Safety Audit Committee at Northern States Power Company. During the past year, Professors Lanning and Todreas continued their service on the National Academy of Sciences/National Research Council's Committee to Assess Safety and Technical Issues at DOE Reactors. Professor Todreas continues to chair the EG&G TMI-2 Accident Analysis Industry Review Group. He is chairman of the Nuclear Safety Research Review Committee (NSRRC); and chairman of the USNRC Peer Review Group on Code Scaling, Applicability & Uncertainty Methodology. He is a member of the DOE-ERAB New Production Reactor Technology Assessment Panel and serves on the review committee of the Reactor Analysis and Safety Division at Argonne National Laboratory.

Professor Henry is a member of the Program Committee of the American Nuclear Society's Mathematics and Computation Division. Professor Driscoll continues to serve on the review committee for the Applied Physics Division at Argonne National Laboratory; he has been appointed chairman for the coming year. For the past two years, Professor Freidberg has served on the Sherwood Theory Executive Committee.

Professor Todreas continues to serve on the editorial board of the Journal of Nuclear Engineering and Design. Professor Henry is on the editorial review board for Nuclear Science and Engineering.

Honors and Awards

Honors were bestowed upon several faculty during the year. The Outstanding Teacher Award for the academic year 1987-88 was presented to Professor Siu by the MIT Student Chapter of the ANS. Professor Brownell received the Coolidge Award from the American Association of Physicists in Medicine. This is the highest award given by the AAPM for accomplishments in medical physics. Professor Gyftopoulos was awarded an honorary doctorate by the Technical University of Athens.

Professor Todreas was elected to the National Academy of Engineering. He was also chosen to receive the Conference Award for the best paper presentation at the 1987 National Heat Transfer Conference. The title of this paper which reported the results of Victor Iannello's PhD thesis research was "Mixed Convection in Parallel Channels with Application to the Liquid Metal Reactor Concept."

Publications

Two books of interest to fusion researchers written by NED faculty have just been published. Ideal Magnetohydrodynamics, by Professor Freidberg, is a graduate-level textbook that covers both the equilibrium and stability aspects of confinement systems, and provides a systematic treatment of this important aspect of magnetic confinement theory.

Principles of Diagnostics, also a graduate-level textbook, provides a systematic introduction to the physics on which plasma diagnostics are based, and thus serves both as a vehicle for entering students and as a reference for experienced researchers. Professor Hutchinson is the author of this publication.

Sabbatical Leave

Professor Sow-Hsin Chen was on sabbatical leave during the academic year 1987-88. He spent six months of his leave in West Germany at the Humboldt Foundation.

Professor Molvig was also on sabbatical during the academic year.

STUDENT ACTIVITIES

The MIT Student Chapter of the American Nuclear Society (ANS) continued its fine tradition of providing service and support to both the student body and the department. Once again this year, they invited guest lecturers to speak at a weekly seminar series. They arranged monthly 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.

Honors and Awards

Scott Peng was elected president of the MIT Graduate Student Council for the next academic year. As president, he will oversee the committees of the Council and represent the Council on various faculty and administrative committees.

Gregory Moore, John Outwater, and Stephen Boerigter received a \$300 award from the IAP Policy Committee for their outstanding work during IAP'88. The students organized three separate activities, including field trips to Seabrook Nuclear Power Plant and Northfield Mountain Pump Storage Power Plant.

A national ANS Scholarship Award was presented to Lisa Porter, an undergraduate, at the the ANS annual meeting that was held in San Diego earlier this month. Ms. Porter was selected for this prestigious award in recognition of her outstanding effort and academic achievement.

At the April pizza meeting, the department announced the recipients of graduate fellowships for the academic year 1988-89. Brian Aviles and David Michael will hold the Manson Benedict Fellowship. Szu-Li Chang will receive the Theos Thompson Memorial Fellowship.

The Sherman Knapp Scholarship for 1987-88 was held by Kenneth Brooks. The award for 1988-89 will be announced shortly.

At the same meeting, two undergraduate students were honored. Ms. Porter was awarded The Irving Kaplan Award for the Outstanding Junior in Nuclear Engineering. Brion Fox received The Roy Axford Award for the Outstanding Senior in Nuclear Engineering.

Scott Haney, a recent graduate in the fusion area, was awarded a prestigious Department of Energy (DOE) Postdoctoral Fellowship. In collaboration with MIT, he will "postdoc" at Lawrence Livermore National Laboratory.

During the academic year 1987-88, DOE Fellowships were held by 11 nuclear engineering graduate students. Magnetic Fusion Energy Technology Fellowships were held by John Massidda and Justin Schwartz. James Crotinger received the Magnetic Fusion Energy Science Fellowship, and Jerry Martin received the Nuclear Energy and Health Physics Fellowship. Recipients of the Nuclear Waste Management Fellowship included Mr. Boerigter, William Hollaway, Patrick Hogan, Tue Nguyen, Scott Simonson, Scott Vance, and Katherine Yuracko.

The National Science Foundation supported Kin Cheung and Terry Turnipseed during the academic year. The Institute of Nuclear Power Operations (INPO) provided aid for three graduate students: Gregory Broadbent, Thomas Hiltz, and Christiana Lui. Argonne National Laboratory funded Dariusz Bushko and Abdel Barakat.

Other graduate students receiving outside support included Warren Stern, a fellowship from the Central Intelligence Agency; Robert Kirkwood, an award from TRW; Warren Krueger, funding from NASA; and David Kennedy, a Whitaker College Surdna Pre-doctoral Fellowship.

In addition to the sources of support mentioned above, over 50 percent of our graduate student body received financial assistance in the form of research and/or teaching assistantships.

SUMMATION

In conclusion, I would like to acknowledge the efforts of the faculty, staff, and support staff of the Department of Nuclear Engineering. Without each individual's assistance, we would not have had a successful year.

NEIL E. TODREAS

Department of Ocean Engineering

OBJECTIVES OF THE DEPARTMENT

Historically, the major activities of the Department of Ocean Engineering have been concentrated on ship design, shipbuilding, and ship operations, all focused further on surface ships. But the major challenges facing the Department are changing, reflecting an evolving national and world view of the importance and functions of the oceans:

- The United States has abandoned the building and operating of ships for foreign commerce.
- The greatest challenges for military ship-system technologies relate to submarines and the environment in which they operate.
- The offshore energy industry is entering a new era in which the need to produce oil and gas at deepwater sites (depths greater than 1000 ft) is forcing the creation of new technologies. In the next decade, one can expect this industry to try again to extract fuel from Arctic waters, thus creating yet other needs for new ocean technology.
- It seems inevitable that the oceans will be exploited in the future as a source of minerals, food, and energy and as a repository for wastes. But our technology for such activities is extremely limited, and we cannot even evaluate the eventual benefits and risks until we can work in the oceans more confidently than at present.
- In the last decade, we have just begun to realize that the oceans are a dynamic environment -- at great depths as well as on the surface -- and that they interact with the atmosphere to have a major impact on world weather and possibly more generally on Earth's energy and chemical balances.

These developments have led the Department of Ocean Engineering during the past year to establish three primary foci for its research and education programs:

- 1) Naval Systems and Operations
- 2) Deep-Sea Technology
- 3) Technology for Ocean Science

Detailed objectives in each of these areas were formulated in the Department's 1988 long-range plan that was submitted to the School of Engineering in December. Within this general framework,

- we will maintain a level of activity relating to surface ships that is adequate for teaching ship design in the Naval Construction and Engineering Program (Course XIII-A);
- our traditional strength in the study of ocean and ship waves will continue to be important because of its role (a) in designing the support systems needed for most deepsea operations, (b) in interpreting ocean-surface images produced with high-altitude sensors, and (c) in understanding the dynamic interactions between the oceans and the atmosphere;
- our unique program in Ocean Systems Management (Course XIII-B) will be developed further at the doctoral level. At the master's level, parts of it will be integrated with other MIT programs, notably the Transportation Program and the Technology and Policy Program.

As we modify our research and education programs to meet these objectives, we will be completing the changes that were envisioned when the name of the Department was changed (from Naval Architecture and Marine Engineering) almost two decades ago.

UNDERGRADUATE EDUCATION

In support of the Institute's efforts to strengthen personal relationships between freshmen and faculty, the Ocean Engineering Department offered five freshman seminars this year:

13.S19 Engineering in Developing Countries and 13.S20 Engineering Leadership (Professor Ernst G. Frankel). The instructor also served as advisor to a group of eight freshmen who took the 13.S19 seminar.

13.S021 Predicting the Velocity of a Sailboat (Professor J. Nicholas Newman). The instructor also served as advisor to the eight freshmen who took this seminar.

13.S16 Computer Aided Design of Complex Surfaces (Professor Justin E. Kerwin). This is actually a six-unit module of 13.00 Computer Aided Hydrostatics and Hull Surface Definition, a regular undergraduate subject, specially structured to provide freshmen with an opportunity to become involved in computer-aided design.

13.S17 Introduction to Computer-Aided Ship Design (Professor Chryssostomos Chryssostomidis).

GRADUATE EDUCATION

In two areas of the Department's teaching programs, significant reorganizations of subjects were accomplished:

(a) The required core subjects in Course XIII-B, Ocean Systems Management, were consolidated into four six-unit, half-term subjects. This tighter packaging retains the essential material in these subjects, while it provides students with some extra flexibility in taking elective subjects. The new format will be offered for the first time this fall.

(b) Several ship design subjects were modified or combined. A major purpose of these changes was to eliminate artificial distinctions between subjects offered primarily to USN officers and those offered to nonmilitary students.

RESEARCH

In March, the Department published a 68-page booklet describing its research programs, written primarily for an audience of non-specialists. The booklet included extended articles on work in six areas, as well as thumbnail sketches of ongoing work in all other areas. It also included a list of graduate degree theses in the last two years. A few highlights from the past year are described here.

Arctic Ambient Noise: Ambient noise limits all activities that depend on the use of acoustic signals for observation and measurements in the ocean. The Arctic Ocean is a particularly noisy environment, because of the presence of an ice cover, but quantitative descriptions of the relevant noise-production mechanisms have not been available. Now Professor Ira Dyer has determined governing fundamental relationships among environmental forces, ice mechanics, and ice fracture radiation. The principal finding is that two mechanisms, winds and currents, cause horizontal stress and moments that at low frequencies give rise to ice cracking and, therefore, noise. This has been tied together via a process model that properly predicts all observables such as peak pressure radiated and time signature.

Associate Professor Henrik Schmidt has been active as well in the study of ambient noise in the Arctic, but from quite different points of view. In one project, he combined field representations for different ice-cracking mechanisms with his state-of-the-art computer model for sound propagation, thereby creating a numerical model, a unique tool, for investigating the importance of cracking-noise directionality in realistic Arctic environments. He has also used his computer propagation models to predict the spatial distribution of ambient noise and thus determine optimal receiver configurations in the watercolumn and in seabed bore holes.

Acoustic-Signal Fluctuations: Professor Dyer is also participating in a study of the effects of ocean dynamics on the fluctuations of signals propagated to long range in the Arctic. The most important of such dynamical motions are internal waves and eddies, and Professor Dyer and his colleagues have shown that the former is more important in temperate oceans, the latter in the Arctic. Professor Schmidt has used his computer propagation models to simulate and then remove propagation effects in actual experimental data. In this way, he and his coworkers have been able to demonstrate a high degree of consistency in the source levels observed in different environments.

Earthquake Hazard to Dry-Docked Ships: Naval submarines and surface ships must be drydocked for extended periods of time for maintenance and conversions. In some parts of the world, including the US West Coast, major earthquakes pose a serious hazard to these ships, some of which cost over a billion dollars

each. So the US Navy has long been concerned with the development of procedures for the docking of ships; the goal is to ensure minimum damage to ships in drydock even in the event of the destruction of a dock. Associate Professor Dale G. Karr and several of his students have developed analyses indicating that current Navy practice is very unconservative. In October, a moderately severe earthquake in Southern California provided an opportunity to test their analyses: Two of his students visited the Long Beach Naval Shipyard and found that a major combatant ship had shifted on its blocks, in accordance with their predictions, although the existing USN docking procedures had implied this would not happen. As a result, the Navy is now revising its docking manual.

Ice/Structure Engineering: The design of structures to operate in Arctic ice is becoming more and more important -- for operating offshore structures, for the transportation of materials through ice fields, and for breaking through the ice by a submarine. The most important engineering information required usually concerns the local and global contact forces that can occur, since these set engineering requirements on man-made structures that must interact with the ice cover. Professor Karr and Professor Tomasz Wierzbicki have examined various idealized, analytical models for such ice/structure interactions. These models are being developed for many different indentation scenarios; they are based on approximations of ice deformation response that range from linearly elastic descriptions to general rate-sensitive constitutive descriptions. Because of the sensitivity of ice strength to confinement conditions, accurate descriptions of the three-dimensional states of stress in the contact zone are of particular importance.

So far this research has been focused on relatively high velocities of impact, which result in brittle deformation of an ice sheet. Three-dimensional elasticity solutions for an edge-loaded sheet have been developed, for which edge tractions are prescribed. Future work will involve the analysis of anisotropic ice sheets. Then it will be possible to predict the contact pressures that result in indentation, spalling, and flaking.

Ducted Propellers: Professor Justin E. Kerwin, Dr. Spyridon Kinnas, and several students have completed the development of a combined vortex-lattice/panel code for designing ducted propellers. Previous methods had either treated the duct/propeller interaction as axisymmetric or utilized a turbomachinery approach (involving a purely interior flow), neither of which is valid. The new code treats the full three-dimensional duct/propeller problem. It has been extensively validated against experimental data, much of which was obtained in the MIT Variable-Pressure Water Tunnel.

Propulsor Inflow Modification and Compound Propulsors: The possibility has long been recognized that propeller efficiency could be raised if the inflow were modified in an appropriate, non-axisymmetric way. Professor Kerwin and his group have worked in the past to develop computer codes to make this possible, and this year they were able to demonstrate the validity of their codes. They designed and tested a stator/propeller combination, confirming the predicted efficiency gain. Moreover, the introduction of the stator caused the complete disappearance of the strong hub-vortex cavitation. The MIT codes are now being used by the Navy for the design of non-axisymmetric stator/propeller combinations, vane wheels, and other compound propulsors. Related codes have also been developed for designing non-axisymmetric ducts, the purpose of which is also to modify the inflow. These have been checked against water-tunnel tests, in which the actual flow field was measured with laser-Doppler anemometers; the agreement between theory and experiment was very good except for the flow prediction in the immediate vicinity of the trailing vortex wake of the duct.

Unsteady Propeller Effects: Professor Kerwin's research on the development of computer codes for unsteady propeller cavitation has ceased for lack of support, but an unusual opportunity arose during the year to confirm the predictions of codes produced earlier. Extensive development efforts have been undertaken in West Germany in connection with the design of a new class of container ships, which will be the most powerful single-screw container ships ever built. Model tests conducted in a West German water tunnel agreed so well with the predictions of the MIT code that a decision was made to use the code for extensive systematic studies of alternate designs. This will be followed by a full-scale test program, which should provide an opportunity for even more rigorous testing of the code.

Towing in the Ocean: It is an everyday experience that ships, barges, and ocean platforms must be towed at sea. These are expensive operations, and they can be dangerous. Moreover, they are technologically complex, but the personnel who conduct such operations cannot be expected to understand fully the basic engineering issues involved. So, for several years, the US Navy has supported an MIT program of fundamental and applied research on towing, with the ultimate goal of providing explicit guidance to ship crews on how to conduct towing operations efficiently and safely.

In its earlier stages, this program was closely linked to Associate Professor Michael S. Triantafyllou's program of fundamental research on cable dynamics. More recently, Professor Jerome H. Milgram and his students have been investigating several related issues, most notably the nonlinear extreme-tension statistics of towing hawsers. This required first the development of the general theory for the statistics of extremes in nonlinear systems. Now the theory is being validated through at-sea measurements of extreme-tension statistics, and it is being used in the preparation of information that will be incorporated into the next edition of the US Navy Towing Manual. Beyond that, Professor Milgram and a USN student are developing computer software for actual on-board use in the management of towing operations; it is intended that eventually the computer will replace the Navy's Towing Manual.

Prediction of Platform Motions: The prediction of wave loads and the response to those loads remains one of the critical aspects in the design of platforms for ocean work systems. Professor J. Nicholas Newman and Associate Professor Paul D. Sclavounos have developed an advanced computer code for this purpose, which is now available through MIT for licensing to industry and government. It makes possible an order-of-magnitude increase in computational efficiency. The code is based on the boundary-integral method, in which the fluid boundaries are represented by many panels, on each of which an unknown quantity must be evaluated. With a large computer, as many as 12,000 panels can be handled by the code, so that accurate representation of realistic geometries is possible. For less complex situations, the code can be used effectively on a microcomputer.

Geometric Modeling: In computer-aided engineering design, it is necessary to represent complex geometrical shapes so that an engineer can analyze and synthesize objects and systems. This need is especially acute in ocean engineering, because the typical objects of design, for example, an ocean platform, are geometrically and functionally very complicated. Many approaches have been devised for geometric modeling by a computer, but previously available systems were based on unreliable algorithms for the solution of intersection and offset problems. These fundamental problems are especially critical in the interrogation of models, the simulation of manufacturing processes, and the representation of dimensional tolerances in a manufactured product. In all of these operations, computational robustness and design repeatability are essential for the geometric modeling systems to function in a truly executive role in automated design and manufacturing.

Assistant Professor Nicholas M. Patrikalakis has demonstrated that there is a close connection between curve and surface representation and the offset and intersection problems. He has shown how to solve these problems in a mathematically exact and computationally algorithmic manner through a new geometrical formulation based on implicit polynomials and, subsequently, B-splines. His approach allows piecewise representation of shapes and provides geometric significance to the underlying coefficients -- both important attributes of a good shape-representation system. His method further enabled him to design and implement a new adaptive subdivision procedure for surface-to-surface intersections.

Professor Patrikalakis' research has significance far beyond the scope of ocean engineering. This is evident just from the fact that it is being supported not only by marine-related organizations but also by the computer-science program of the National Science Foundation and by the General Electric Company.

Tethered Underwater Vehicles: The development of remotely operated vehicles (ROVs) for many underwater operations is critically limited by the need for a tether, which may be needed for powering, control, and data transmission. The Argo, which was used by the Woods Hole Oceanographic Institution (WHOI) in the successful search for the Titanic, operates on tethers longer than 4,000 meters. Associate Professor Michael S. Triantafyllou has been collaborating with WHOI scientists in the study and design of the tethers for Argo and other WHOI ROVs. In controlled experiments in 1987 on a 1,200-meter cable in the USN AUTECH range, vortex-induced vibrations were measured, yielding exciting new insight into the occurrence and mechanisms of these complex phenomena.

Crashworthiness and Structural Failure: Eleven automobile manufacturers in the United States and Europe have now joined the consortium supporting Professor Tomasz Wierzbicki's program of research on crash mechanics of thin-walled structures. During the year, a US Navy officer student applied some of the concepts developed in this program to the analysis of the structural response of a boxlike structure to an internal explosion.

As a more general approach to the quantitative analysis of catastrophically loaded structures, Professor Wierzbicki and his coworkers have developed a "superfolding element" that can be embedded into computer codes based on the finite-element method (FEM) for structural analysis. This new element contains within itself the fundamental mechanics of a folding thin-walled structure; it can replace hundreds of conventional elements in an FEM computation, reducing computer time for solution by orders of magnitude.

FACILITIES

The MIT Variable-Pressure Water Tunnel is a crucial facility in one of the Department's largest research programs. In November, the impeller drive in the water tunnel failed suddenly and catastrophically and had to be replaced. The Bird-Johnson Company manufactured a new stainless steel shaft (at no cost for machine time), and laboratory staff and students removed and replaced the 19 stator blades and the 450-pound impeller. The new drive was started up on December 30, and, as Professor Justin E. Kerwin reported, "We were pleased to find that it runs better than I ever remember the old system running."

The Department's own cluster of terminals for Project Athena became fully operational this year, and it is receiving heavy use by students for their classes and by faculty in their curriculum-development projects.

BOOKS BY FACULTY MEMBERS

Professor Ernst G. Frankel published a new book this year, The World Shipping Industry -- Its Economics and Policies (Croom Helm, London/Boston).

PATENTS

Professor Jerome H. Milgram was granted a patent (#4,676,899, June 30, 1987), "Tankship On-Board Oil Leak Treating System," with rights assigned to MIT. The system provides a mechanism for ultra-rapid mixing of dispersant with hydrocarbons in a ship tank after the tank has been ruptured, thus minimizing damage to the surrounding environment. A firm in Scotland has expressed an interest in obtaining a license.

CONFERENCES

Associate Professor Judith T. Kildow and Professor Koichi Masubuchi, with support from MIT's Industrial Liaison Program (ILP), organized a symposium, The Oceans in the 21st Century: Bringing Advanced Technology to the Ocean Industries, October 5-6, 1987. Experts representing government, industry, and universities in the United States, Japan, and Europe examined areas in which emerging technologies can be directed to the solution of important ocean engineering problems.

Professor J. Nicholas Newman was co-organizer (with Professor David Evans, University of Bristol, UK) of the Third International Workshop on Water Waves and Floating Bodies, held at the Swope Center in Woods Hole, Mass., April 10-13, 1988. The first workshop was held at MIT in 1986 and the second at the University of Bristol (UK) in 1987. These workshops are rapidly becoming an international focus for discussions among research leaders in this critical area of ocean engineering.

Professor Tomasz Wierzbicki was co-organizer (with Professor Norman Jones, formerly of MIT, now University of Liverpool, UK) of the International Symposium on Structural Failure, held in the Kresge Little Theatre June 6-8, 1988. International Journal of Impact Engineering and International Journal of Mechanical Sciences devoted entire issues to the publication of some of the symposium papers, and the invited papers are being published in a separate book.

FACULTY AND RESEARCH STAFF

Professor Martin A. Abkowitz retired at the end of the year, completing 39 years of service on the MIT faculty.

Professor Arthur B. Baggeroer resigned as Director of the Joint Program of MIT and the Woods Hole Oceanographic Institution at the end of the year. He served in this position for five years, and he now returns to fulltime teaching and research.

Professor A. Douglas Carmichael has been appointed 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.

Professor Odd M. Faltinsen, from the Norwegian Technical University in Trondheim, was a visiting professor during the academic year. He is one of the world's leading authorities on problems of ships and platforms in waves, and in recent years he has extended his research to problems of vortex shedding by a bluff body in a stream. Professor Faltinsen took an active role in both the research and education programs of the Department during his visit.

Dr. Spyridon Kinmas, after working as a post-doctoral associate in the Department, was appointed Research Engineer. He is conducting research in propeller hydrodynamics and design and providing guidance to several graduate students under the general supervision of Professor Justin E. Kerwin.

Associate Professor Henry S. Marcus was on sabbatical leave this year, spending much of it working in the Office of the Assistant Secretary of the Navy in Washington on research on shipbuilding and logistics.

Assistant Professor Amiram Moshalov resigned at the end of the year to take a faculty position at Tel Aviv University in Israel. He had joined the MIT faculty in 1985. He and his wife served as faculty residents in an MIT undergraduate dormitory for two years.

Assistant Professor Nicholas M. Patrikalakis was named Doherty Professor in Ocean Utilization for two years. He will use the funds made available to him by the professorship to support his research on shape representation in the computer-aided engineering of marine systems.

Dr. Henrik Schmidt joined the faculty in September as Associate Professor of Ocean Engineering. He had previously been a scientist at the NATO Antisubmarine Warfare Research Center in La Spezia, Italy.

Associate Professor Paul D. Sclavounos was awarded tenure this year. He spent the year on sabbatical leave at the California Institute of Technology, performing research on lifting and free-surface flows.

Professor Barrick F. Tibbitts received the Legion of Merit Award from the President of the United States "for exceptionally meritorious conduct in the performance of outstanding service as director of the Ship Design Group of the Naval Sea Systems Command from August 1984 to May 1987." Professor Tibbitts, who joined the faculty just a year ago, also received an MIT award for outstanding teaching at the graduate level.

T. Francis Ogilvie

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, 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 W. Eric L. Grimson, Professor Ellen Hildreth, Professor Berthold K. P. Horn, Professor Tomaso Poggio, and Professor Shimon Ullman (on leave from the Laboratory) do research in computer vision. Professor Christopher G. Atkeson, Professor Rodney A. Brooks, Professor John M. Hollerbach, Professor Tomás Lozano-Pérez, Professor Marc Raibert, Professor Warren 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. 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 177 members include 20 faculty members, 10 academic staff, 40 research and support staff, and 107 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, Digital Equipment Corporation, General Motors Research Laboratories, General Electric Company, NATO, Standard Oil Company, Schlumberger, International Business Machines, Hughes Research Laboratories, Sperry, Exxon Research and Development Company, NASA, NYNEX, General Dynamics, Lotus, Sandia National Laboratory, Siemens, Olivetti, Analog Devices, Apple Computer, Sloan Foundation, and Bear Stearns Company.

ROBOTICS

Mobile Robots

Professor Brooks and his staff and students have been building mobile robots and testing their theories of how to organize intelligence. There are two key ideas. First, the robot control system is decomposed into a parallel collection of complete but simple task achieving behaviors. Second, the complexities of sensor fusion are avoided by using an approach called sensor fission. Different sensor inputs or differently processed sensor inputs provide partial world models to individual task achieving behaviors. Intelligent behavior comes about by fusing the planned actions of these behaviors. During the past year this architecture has been implemented on a number of new robots, including one with an onboard laser light striper for 3-D perception, and a lightweight manipulator. Progress has also been made on another robot which uses a number of real time vision algorithms to support the control architecture and has a new onboard real-time low power vision processor. Additional development of the control architecture has resulted in a compiler for it which outputs gate level circuit descriptions. These gate level programs have been tested on dynamically reconfigurable gate arrays. This development shows that it will be possible to build intelligent robots with very small silicon areas for computation opening up a whole new field: the microbot, the mechanical analog of the microprocessor.

Planning For Collision-Free, Compliant, and Grasping Motions

Professor Lozano-Pérez and his associates have developed and tested 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 to enable it to plan the motion of two robots, one equipped with Dr. Salisbury's three-fingered hand. The system has also been provided with the capability of verifying the position of a grasped object by locating the image of a projected light stripe on a corner of the grasped object.

Legged Locomotion

Professor Raibert and members of the Leg Laboratory are studying legged locomotion in robots and animals. In earlier years the group demonstrated dynamic machines that balance as they run. 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. In the past year new algorithms were developed for controlling the stride of legged systems, enabling a biped running machine to climb up and down a short flight of stairs. One running machine ran on stilts to accomplish a new top speed of 12.8 mph. Experiments with a quadruped showed that a single set of control algorithms could be adapted to control three separate quadruped gaits: trotting, pacing, and bounding. Professor Raibert has established a collaboration with Professor Thomas McMahon of Harvard University in an attempt to use knowledge of running robots to further the understanding of running animals. Biomechanical experiments on dogs, goats, and horses are currently underway.

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. He is developing, with Professor Ian Hunter of McGill University, an experimental system for determining the joint mechanical properties of the human arm during movement using nonlinear system identification techniques and a perturbation system involving air jets. With Professor Jeffrey Lang of the Laboratory for Electromagnetic and Electronic Systems and Professor Hunter, he is designing a new direct-drive arm with new motors specifically designed for robotics, involving thermal management, high torque to mass ratio, and torque linearity. He has been involved with the CONDOR real-time architecture for control of the Utah/MIT hand, which is becoming widely distributed for generic robot control applications.

Professor Atkeson and his group explore 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 current emphasis is 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 is 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.

The Salisbury articulated hand has been mounted on a robot arm and integrated into the path planning system developed by Professor Lozano-Pérez. It has been used to demonstrate multi-arm collision-free paths of hands and arms. A force sensing finger is now operational on this system and has been used to discriminate between objects with different friction properties. A number of simple reflexive grasping behaviors have been developed, characterized, and tested on the Salisbury hand. The behaviors enable a wide range of objects to be acquired without explicit planning.

A new high performance cable driven arm has been built by Dr. Salisbury's group. It is designed to contact the environment with any of its surfaces and perform a number of novel and useful pushing and grasping operations. Patent applications have been filed for the efficient, stiff, zero-backlash transmission in the arm as well as the compact cable differential mechanism used in the shoulder. In a collaborative effort with Woods Hole Oceanographic Institute, a second arm employing these advances has been built for underwater use.

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. The group has also developed means for improving the response of a robot to information obtained from sensors built into the robot.

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 design and debug a concept for a mechanical system given the performance specifications for the system. A second program transforms a schematic description of a design to a detailed design by optimally choosing system components.

VISION

The Vision Machine

The main project of Professor Poggio's group is 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 our progress in the theory of early vision algorithms, their parallel implementation, and their integration. The Vision Machine consists of a movable two-camera Eye-Head system—the input device—and a 16K Connection Machine—the main computational engine. We 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, based on coupled Markov Random Field models, 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. We have interfaced the output of our integration stage with a parallel recognition algorithm. We are also beginning to study analog and hybrid VLSI implementations of the Vision Machine 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.

Stereo Vision

Professor Grimson and his students are developing stereo vision systems able to support intelligent tasks such as object recognition and autonomous vehicle navigation.

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 on a variety of scenes, 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.

Motion Vision

Professor Horn and his students continue to work on problems in motion vision. One aspect of this research involves the extension of previous work on recovering instantaneous translational and rotational velocities to motion recovery over extended periods of time using Kalman filtering approaches. These filtering methods are applied in two entirely different ways to the estimation of the vehicle state and the estimation of the shapes of the surfaces of objects in the environment. Other work concentrates on exploiting the reduction in the number of degrees of freedom that occurs when the camera tracks or fixates a point in the environment.

Integrated Circuit Networks

Professor Horn and his students are also working on designs of integrated circuit networks for many of their early vision algorithms, including those for binary images and direct motion vision. Recently an equivalence between two apparently quite

different ways of using resistive networks in these computations has been demonstrated. This equivalence will help us choose the simplest network for a given computation. In another area, a novel interlaced layout of nodes of image points at multiple resolutions has hinted at ways of designing systems that can deal with a hierarchical arrangement of image data at multiple scales. In a related development, a method for solving the two-dimensional heat-equation by mapping the time dimension into a third spatial dimension has been discovered. This method will simplify the convolution of image data with Gaussian kernels of varying size, an operation frequently used in edge detection, for example. It will also allow image computations to proceed continuously, rather than in a clocked fashion.

Visual Motion

Professor Hildreth's research addresses a range of problems in the analysis of visual motion, including the computation of an image velocity field, the design of multi-resolution algorithms for motion analysis and the recovery of three-dimensional structure from relative motion. Recently, her work has emphasized the use of motion information for tasks such as navigation. She has explored how simple estimates of the time-to-collision of the observer with object surfaces can be used to recover the three-dimensional trajectories of moving objects and to avoid obstacles and track moving targets while navigating through the environment. Perceptual experiments are being conducted to test computational models of the use of time-to-collision information.

NATURAL LANGUAGE

Professor Berwick and his colleagues are building the next generation of natural language parsers and translators, based on modular linguistic theories. During the past year, his group developed a universal representation for word meaning that considerably improves existing language translation systems and that will let us tackle translation tasks that have never been successfully handled. A formal framework for analyzing modular systems was also invented; this allows one to "compile" modular language systems into a more efficient format and will permit the exploration of parallel computation speedups in natural language processing. Finally, a new collaborative effort into the design of modular language processors was begun jointly with the Cognitive Science Center.

LEARNING AND COMMONSENSE REASONING

Professor Winston's theory of reasoning by analogy consists of the following parts: an English-understanding module, developed and implemented by Dr. Boris Katz, that converts prepared text into relations in a semantic network; a cause-dominated matcher that finds the best possible correspondences according to the causal framework determined by the situations themselves; an analogizing module that reaches conclusions about a given situation by using a remembered precedent; and a rule builder that constructs if/then rules. Professor Winston extended the theory to the problem of learning what things look like from functional definitions, prior knowledge, and particular examples.

Dr. David Kirsh has been developing a new approach to planning that focuses on resource management. Precedents are called on to help decide what resources an agent should take on a mission and also to help decide how to control the use of resources. The virtue of this approach is that it provides a way of thinking about planning that explains why constraints should hold between actions or subgoals.

Other work in the group includes efforts on programs that discover and use concepts in a variety of technical domains, and 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.

Related work has been the study of the dynamics of everyday activity. Realistic domains are characteristically complex, uncertain, and constantly, uncontrollably changing. This makes planning and reasoning with representations very difficult. New representations called indexical-functional representations which exploit the regular pattern of interactions that emerge between creatures and their environments have been developed. This theory is now being implemented in a program called Pengi, which is effective in a domain that is too complex, uncertain, and fast-moving for previous techniques to handle.

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 large 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, exploring in detail the payoff from the process, providing a set of guidelines that indicates when to remember and generalize, and when to simply re-derive the result; a system to do geologic interpretation that combines the robustness of a model-based reasoning system with the efficiency of a rule-based system; a system capable of designing representations for an interesting class of analytical reasoning problems; and a system capable of solving the problem of predicting how and why a system will react to perturbations, using a newly developed technique called differential qualitative (DQ) analysis.

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 under the Engineering Research Center Initiative and was established in May, 1985. This Center was recently approved for an additional five years of support beginning in 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 involvements. 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 1987, a total of seventeen faculty members participated in the Center's activities. Within M.I.T., three departments from the School of Engineering have faculty participants: Chemical Engineering, Electrical Engineering and Computer Science and Nuclear Engineering. From the School of Science at M.I.T., faculty participants are from the Department of Biology, Department of Applied Biological Sciences and the Whitehead Institute. Lastly, the Department of Chemistry of Harvard University has joined the faculty ranks of this Center. A total of 236 people were affiliated and/or were supported by the BPEC in 1987-1988. This included 17 faculty members, 89 undergraduates, 51 graduates, 16 post-doctoral associates, 22 technical support and administrative personnel, 10 industrial visiting scientists and engineers, 3 visiting professors and 28 non-M.I.T. undergraduates.

The major financial support is provided by the National Science Foundation. Educational support for undergraduates and graduates was partially provided by the National Institute of Health (NICMS). Financial support in the forms of industrial contracts and equipment were provided by 36 companies. Lastly, unrestricted funds and gifts to the Center in 1987-1988 were from 53 companies.

EDUCATIONAL ACTIVITIES

The BPEC faculty members continued to teach an intradisciplinary undergraduate course 7.52J/10.56J/-20.803J, "Biotechnology of Mammalian Cells". Thirty-three students attended this course from three separate M.I.T. departments. The Undergraduate Research Opportunities Program (UROP) continued to be an active program within the BPEC. In 1987-1988, a total of 89 M.I.T. undergraduates from 13 different departments participated in the Center's UROP activities. An undergraduate outreach program funded separately by the National Science Foundation under the Research Experience for Undergraduates (REU) was initiated in 1987. During 1987-1988, 28 non-M.I.T. undergraduates participated in the BPEC research programs from 12 different colleges and universities. Lastly, an industrial internship program was launched by this Center to allow undergraduates to perform research at industrial sites during the summer of 1988. Eight M.I.T. undergraduates participated in this internship program at six industrial sites.

At the graduate level, continued efforts were exercised to bring about intradisciplinary courses taught by the Center's faculty. Three joint courses were presented during 1987-1988. An innovative program to improve the quality of graduate education was implemented in the spring of 1988. This was the use of video tapes of industrial practices to complement classroom teaching. Video tapes were prepared at two sites, Associated Biotechnology Engineering Corporation and Eli Lilly and Company, and these tapes were subsequently used to illustrate the practical aspects on the theories presented in the graduate course on "Biochemical Engineering".

Educational activities directed at the industrial sector were achieved through the special summer program at M.I.T. In 1987, four special summer courses under the auspices of the BPEC were presented and these were: "Fermentation Technology", "Biotechnology: Principles and Practices", "Downstream Processing", and "Modeling, Simulation and Optimization". In 1988, a new initiative was implemented by the BPEC where a 4-day course was taught at an industrial site. Five BPEC faculty members jointly taught a special course entitled "Downstream Processing" at the West Point facility of Merck, Sharp and Dohme.

CURRENT RESEARCH

The vision and goal of this ERC are to develop advanced concepts for the manufacturing of complex proteins and to train a new breed of professionals with the cross-disciplinary skills needed to support the biotechnological industry. Many therapeutic proteins cannot be made in prokaryotic organisms and thus new concepts are needed to synthesize and recover these materials from animal cell cultures. The research thrusts of the BPEC are designed to solve near and long term problems, and as such, have impact on US biotechnological manufacturing capability 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 process 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 technology, 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 chromatographic processes recognizes the importance of immunoabsorption and addresses the barriers of operating 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 also important goals of this Center. Collaborations with the biotechnology industries were accomplished through 21 joint projects and 17 industrially supported contracts in 1987-1988. The BPEC Industrial Consortium Program has a total of 52 companies who subscribe to the Center's activities. Lastly, 10 industrial scientists and engineers were in residence in this Center for periods of one month to one year in 1987-1988.

To affect the timely and efficient transfer of technology, two separate offices are presently in operation. The Technical Coordination Office handles the visits from companies, annual symposium and special workshops. For example, the third Annual BPEC Symposium was held in October, 1987 with a total attendance of 420 people from 150 companies. The special workshop held in June, 1988 for the BPEC Consortium members on "Advances in Membrane Technology for Bioprocesses", was attended by 60 people representing 36 companies. Lastly, in 1987-1988, a total of 83 companies visited the BPEC at M.I.T. A Technology Transfer Office was recently created in 1988 to devote special efforts to affect transfer of technology and personnel between this Center and the industrial sector. The goal of this office is to provide a means for transfer of both knowledge-based and deliverables from the various research programs in the Center.

NEW APPOINTMENTS

Professor George M. Whitesides, Department of Chemistry, Harvard University, joined the Biotechnology Process Engineering Center in 1988. Professor Whitesides and his group are conducting collaborative research with other Center faculty members dealing with the behaviors of surfaces in biological systems through organic chemistry. Dr. Michael P. Thien and Dr. Martin Griot were appointed as coordinators in the Technology Transfer Office.

DANIEL I. C. WANG

Center for Advanced Engineering Study

The Center for Advanced Engineering Study (CAES) was founded in 1963 for the purpose of developing educational programs that provide opportunities for practicing engineers, scientists, and managers in industry, government, and educational institutions to attain and maintain the competence needed to exert technological leadership. Alfred P. Sloan Jr. provided both the impetus and the funds to get the Center started. Building 9 has been the home of CAES since its completion in 1968. 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, on-campus and at the workplace, for the practicing professional. The on-campus program, called the 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. For learners at the workplace, the Center provides studio-based and classroom-based video courses, as well as video-taped 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.

During the 1987-88 academic year, 63 professionals participated in the Advanced Study Program, 25 from the United States and 38 from 12 other countries. These Fellows attended regular graduate and also 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. Moreover, the Center sponsored several projects that are of particular interest to the Fellows, such as Project Management, Systematic Policy Analysis, and Management of Technological Change. These subjects are listed in the catalog and are, of course, open to MIT students. CAES also 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. We also offered a weekly luncheon seminar at which the Fellows gave brief presentations on their work. Center staff and faculty also made 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.

During 1987-88, CAES videotaped a number of MIT symposia on current research activities for timely distribution to industrial organizations and educational establishments. The symposia, which were organized by the Industrial Liaison Program, included such diverse topics as Frontiers in Metallurgical Research; Computer Models and Modeling for Negotiation Management; Speech Communication and Processing; High Temperature Superconductivity: Implications for Industry; and Emerging Materials and Processes.

In addition, the Center videotaped several Summer Session courses in 1987. Those videotaped and marketed include Mathematical Modeling by Professor Julian Szekely and Data Networks by Professors Robert Gallager, Dimitri Bertsekas, and Pierre Humblet.

In February, 1988 MIT faculty and staff participated in the inauguration of the new CAES professional-quality television facility. Designed to meet the diverse video needs of the Institute, the television studio complex has increased Center productivity, enhanced video production, and facilitated the application of new video technologies. New productions include: Image Processing by Professor William Schreiber, Analysis of Welded Structures by Professor Koichi Masubushi, and Machinery Noise and Diagnostics by Professor Richard Lyon. CAES video programs continue to be produced entirely with Center staff and Center-owned equipment.

The summer of 1988 will be the second year of CAES 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. One hundred and seventy-two faculty members from 105 US colleges in 36 states will have participated in these courses. The topics include, among others, Artificial Intelligence and Robotics. CAES plays a key role in the organization, coordination, and administration of this program under the aegis of the American Society for Engineering Education (ASEE).

The Center will continue to explore emerging educational methodologies and communications technologies. Special emphasis is being placed on the development of collaborative programs with a wide range of business, public sector, and academic organizations.

For example, educational programs we are considering include concentrated on-campus courses for professionals in local industry as well as satellite uplinking of special programs for direct interaction with industrial sites nationwide.

SHAUL EZEKIEL

Center for Technology, Policy, and Industrial Development

In its third year, the Center for Technology, Policy and Industrial Development (CTPID) has achieved its initial objectives, added new projects, and continued to support research and education in science- and technology-intensive policy issues. Approximately 80 students, faculty, and staff actively contributed to new and ongoing work at CTPID. Of particular note this year have been the establishment of an external advisory board with distinguished members from industry and government; the development of a diverse and provocative group of educational and research projects associated with the Hazardous Substances Management Program; the expansion of the research interests, staff, and industrial support of the International Motor Vehicle Program; and the participation of many Center affiliates in the MIT Commission on Industrial Productivity. The Center's educational branch, the Technology and Policy Program, won the Irwin Sizer Award for the Most Significant Improvement to MIT Education.

The Center brings together a wide range of MIT resources in science, engineering, the social sciences, and management to address policy issues with significant scientific and technological components. A major theme of the Center's educational and research activities is how to utilize technology to further industrial development in a socially responsible manner. In this era of international interdependence and extensive competition between companies and countries, technological innovation and adaptation are important factors affecting industrial growth. Center researchers are investigating the scientific and social processes by which new technologies are identified and deployed. Of particular concern are the impacts on society of alternative technological choices and the most equitable and appropriate ways to manage technological change.

Research at CTPID is aimed at developing and applying new quantitative and qualitative approaches to technology and policy issues. However, even with complete technical information, our current systems for decision making often generates divisive adversarial debate and forestalls time resolutions. Therefore, concurrent with the pursuit of technically sound bases for decisions, the Center is promoting the development of more effective decision-making techniques involving risk assessment, risk management, and negotiation.

The Center, with its dual traditions of responsiveness to public issues and academic neutrality, can provide objective analyses of policy options, rather than support for any particular position. In all its major initiatives, CTPID has included the perspectives of leaders in government, industry, and labor. Center projects routinely go beyond basic research to implementation activities to demonstrate how an interface between technology and policy may be effected. Projects and programs are frequently structured to include seminars, forums, and conferences designed to bring together people with differing perspectives on challenging issues; they are encouraged to work toward consensus and to identify specific policy alternatives.

On October 14, 1987 the Center's External Advisory Board met for the first time. The purpose of the Board is to advise the MIT administration on directions for the Center. Professor Gerald Wilson, Dean of the School of Engineering, charged the Board with two questions "Is the Center's area of activity right?" and "Is the Center's approach right?"

Members of the External Advisory Board are Dr. Arthur Gelb, Chairman, President of The Analytic Sciences Corp.; Dr. Alan A. Altshuler, Dean, Graduate School of Public Administration, New York University; Edgar L. Ball, International Secretary, United Steelworkers of America; Jay W. Chai, Executive Vice President, C. Itoh & Co.; Antonia Chandler Chayes, Chairman, Endispute Incorporated; Dr. Edward E. David, Jr., President, Edward E. David, Inc.; Donald F. Ephlin, Vice President-Director, General Motors Department, United Automobile Workers Union; Dr. George Hatsopoulos, CEO & President, Thermo Electron Corp.; Dr. William Hogan, Professor of Political Economy, JFK School of Government, Harvard University; Kenneth F. Holtby, Senior Vice

President, The Boeing Company; John P. Horton, President, Rokalor, Inc.; Ralph Landau, President, Listowel Inc.; Richard A. Meserve, Covington & Burling; Bernard Rabinowitz, CEO and President, Atlantic Industries, Inc.; William Ryan, Environmental Program Director, Masspirg; Ray Stata, President, Analog Devices; The Honorable John H. Sununu, Governor, State of New Hampshire; Robert M. Weinberg, Real Estate Development.

RESEARCH

The Hazardous Substances Management Program

The Hazardous Substances Management Program, a major MIT initiative being administered by the Center, has completed its second year of activity. The Institute has made the problem of hazardous substances a concern of highest priority for research and education for the next decade. The Program is designed to explore the problems posed by hazardous chemicals emanating from all sources, including purposeful use, effluents from manufacturing, and the disposal of wastes.

During 1987-88 the Program has succeeded in attracting sponsors, meeting its priority goals, and consolidating plans for future development. Major corporate sponsors now include the Dow Chemical Company and Montedison. Additional Program support has been provided by Mobil, Dupont, the State of New Hampshire, and the Environmental Protection Agency.

The basic research being pursued under the program is designed to lead to fundamental scientific, technological, and policy breakthroughs. Three objectives underlie this effort:

*Those working in this area will develop new approaches in public and private decision making that can break the present logjam surrounding siting, regulation, and policy making. They hope to replace technocratic, top-down approaches to policy and conflict resolution with a consensual, participatory approach to policy development and conflict avoidance.

*Researchers are developing new methods to provide direct evidence of the effects of chemical exposure on human health that will permit wiser setting of priorities, identify feasible technological approaches to mitigating hazards, and objectives for risk management. The aim is to replace the present inferential basis for science-intensive decision making, fraught with uncertainty and implicit value judgments, with a more scientifically defensible system.

*MIT and industry scientists will work together to develop innovations in product and process technology that will help us avoid the creation of wastes and dangerous products in the first place. The shift is obvious--from emphasis on waste management to waste reduction and elimination.

These long-term paradigm shifts will be augmented and supported by new knowledge gained through research aimed at problems requiring immediate solutions. The immediate results of the programs will be advances in the technologies available to solve short-term problems, particularly applications in incineration and the resolution of current disputes over the safety of these technologies. In the long run, the program should produce permanent changes in our overall approach to hazardous substances.

The educational component of the program is designed to provide a strong background for both undergraduate and graduate students specializing in this field. Four courses are being offered in this area sharing a common theme: Chemicals in the environment. They are subtitled "Sources and Control", "Chemicals and Human Disease", "Fate and Transport", and "Policy and Management". This highly successful grouping of courses is team-taught by members of the Hazardous Substances Group and other faculty members from several departments.

In September 1987, a series of policy analyses was inaugurated, beginning with a study of incineration led by Professor Lawrence E. Susskind and Dr. John Ehrenfeld. The approach adopted by program researchers was designed to address the present gridlock stalling efforts to regulate incineration and to site facilities. Investigators first identified major areas of conflict and organized findings into a small set of issue areas.

The most important issues surrounding incineration need to be considered in the context of waste reduction and alternative technologies; safety and the nature and magnitude of the risk to human health and the environment; reliability, including ways to guarantee that a facility will operate as planned; and fairness, including how to involve all interested parties in the decision-making process.

These issues were considered at an invitational conference, "Hazardous Waste Incineration: Confronting the Sources of Disagreement". The meeting brought together people who disagree about the need for incinerators, their safety, and the fairness of decisions to explore options that will lead to action. Participants first discussed the positions of the key groups active in the incineration debate, outlined in a paper prepared by the Hazardous Substances Management Group. They were then asked to suggest ideas for dealing with the conflicts more effectively. Suggestions fell into five areas: public participation and education; protocols for monitoring and enforcement; frameworks for analyzing risks; testing and certification of facility operators; and connection of incineration with other options. Following the meeting, conference organizers will work with participants to design specific programs for action in these areas. The conference is an example of how the program is working to couple new technology with new models to shape the way we see the world and take individual and collective action.

Also in September 1987, the program began a one-year study of hazardous wastes not presently regulated under the federal statute governing the management of hazardous waste. The project is being funded by the Environmental Protection Agency at a level of \$150,000.

The program is beginning a two-year study for the State of New Hampshire to develop a plan to guide policies and programs for the management of household hazardous wastes, other nonregulated wastes, and municipal solid wastes that are also potentially hazardous. The project will involve the creation of a participatory decision-making process to guide the study of several issues, including small treatment facilities, incineration, siting, and new institutional mechanisms to oversee the proper management of these kinds of wastes.

Research by Professor Michael A. Celia on groundwater models for predicting pollutant transport is being directed toward several currently unresolved problems in the field in two areas. The first area involves fundamental physics of fluid movement when multiple fluids occupy the pore space of a porous medium. The second is directed toward developing improved numerical simulation methods to allow meaningful solutions to be obtained. The ultimate goal of this research is to develop physically realistic models that may be used as practical tools in the solution of field problems.

MIT has become one of four universities to receive grants in the first year of a five-year program in which the National Institute of Environmental Health Sciences is supporting basic biomedical research into the effects of hazardous substances on human health. Authorized under the Superfund Amendments and Reauthorization Act of 1986, the new research will combine basic investigations in the fields of engineering and geosciences with a biomedical research program core. The core is designed to provide a broader and more detailed body of scientific information about the effects of hazardous substances.

The involvement of industry is critical, not only to supporting the program but also to identifying accurately the general and specific points at which problems may be avoided or most economically resolved. The Hazardous Substances Management Program is actively seeking ideas from the industrial sector. A committee of industry and government representatives advises the MIT faculty group determining the research agenda. Insights from all sectors will be shared through technology transfer, joint research projects, seminars, and other mechanisms.

The program now underway is being shaped by a group of faculty members, the Hazardous Substances Group, presently including Professors David Marks; Daniel Roos; Adel Sarofim, (Department of Chemical Engineering); Lawrence Susskind; and William G. Thilly, Head of the Center for Environmental Health Sciences. Dr. John R. Ehrenfeld, Senior Research Associate at CTPID, is coordinating the program and also teaching two of the four basic courses.

The International Motor Vehicle Program

During 1987-1988, the International Motor Vehicle Program (IMVP) reached the mid-point of its four-year mandate. The year was marked by several significant events, mainly focused on the European segment of the world wide automotive manufacturing system. The IMVP was established in 1986 to examine the evolution of the industry and assess the issues facing the auto-producing world as companies strive to define and achieve the next phase of "best practice" in the industry. The multimillion dollar program is coordinated at MIT and directed by Professor Roos.

The Program draws on the resources of government, industry, and academia to develop new perspectives on this important world industry. A network of researchers from the seven dominant auto-producing countries, and from those having new and growing auto industries, is addressing issues that affect all aspects of this increasingly internationalized business. IMVP researchers are developing a view of the automobile industry as an interlocking system, in which technology, human resource management, international economics, and political conditions worldwide must be considered in the making of effective public and private policy.

The Program's annual series of meetings included the meeting of research affiliates, and the seminar for suppliers of auto industry parts and components, cosponsored by the Motor Equipment Manufacturers Association, in September 1987. In November, the Program hosted a visit by Vittorio Ghidella, President and CEO of Fiat Auto.

In May 1988, the Program held the second in a series of International Policy Forums. The meeting, held at the Villa d'Este on Lake Como, Italy, focused on the future of the European motor vehicle industry in light of increasing international competition, the recent realignment of currencies, and the proposed economic unification of Europe in 1992. The Forum provided an opportunity for Program researchers to share research findings with senior leadership of the automotive industry from government, manufacturing, and labor, and to gauge the nature of their most pressing concerns.

Under the sponsorship of the Office of Technology Assessment, Program researchers undertook a major case study of the attractiveness of the United States as a location to design, engineer, fabricate, and assemble motor vehicles in the 1990s.

Program research made significant contributions to the work of the MIT Commission on Industrial Productivity this year. Motor vehicle and parts production remains the largest segment of the US industrial base. The work of the IMVP and its predecessor programs has provided the most extensive and complete body of data for analyzing the complex phenomenon of productivity, particularly as it may be affected by foreign competition. Professor Roos heads the Commission's sector group on automobiles.

The Program staff at MIT has been augmented this year by Program Coordinator John P. O'Donnell. He has taken over the vital task of maintaining active liaisons with Program sponsors world wide.

In 1987-88, the IMVP gained four important new sponsors based in Europe, Renault, Fiat, Peugeot, and the Commission of Common Market Automobile Constructors. Their support reflects growing awareness of the need for comparative research on the part of European automotive interests and amplifies the capacity of Program researchers to investigate the European side of world wide best practice.

Material Systems Laboratory

The Material Systems Laboratory (MSL) uses an analytical framework based on economic and engineering assessment to perform industry-sponsored research in the dynamic competition between materials for end use applications. The materials examined are used in the automotive, aerospace, construction, semiconductor, telecommunications and machinery markets. The specific materials analyzed are high strength steels, aluminum alloys, copper alloys, superalloys, stainless and alloy steels, powder metals, metal matrix composites, structural ceramics, polymers, and composites.

The MSL is a part of both the Materials Processing Center and the Center for Technology, Policy and Industrial Development. Joel P. Clark, Professor of Materials Systems in the Department of Materials Science and Engineering is Director of the Laboratory.

The MSL has three forms of sponsorship. Project Sponsors support one of the current projects. Laboratory Affiliates support all active projects for periods of two years or longer. Laboratory Sponsors act as Laboratory Affiliates and in addition act as members of the MSL steering committee. Current sponsors include the Aluminum Company of America; Akzo Enko Plastics; Carpenter Technology Corporation; Chrysler Corporation; DSM; Research and Patents, Dupont Company; Exxon Research and Engineering; Ford Motor Company; General Dynamics Corporation; General Electric Company; Hoogovens Group; Inland Steel Company; Interlake, Inc.; LTV; Montedison; McDonnell-Douglas; Oak Ridge National Laboratory; Noranda; Pohang Iron & Steel; Owens-Corning Fiberglass; Texas Instruments; and USX.

Projects pursued in the MSL during 1987-88 included Materials for Automobile Doors, investigated by Scot Arnold, Joonchul Park, and Frank Field for the Door Study Group; Surface Mount Printed Wiring Board Materials, investigated by Lee Hong Ng; Mainframe Ceramic Substrate Materials, researched by Scott Sikorski; Markets for Powder Metals, analyzed by Young Han; Aerospace Composite Materials, undertaken by Barbara Masi; and Structural Ceramic Coatings, researched by Olivier de Botton.

International Competition in High Technology

"International Competition in High Technology" is a project that has focused on US/Japanese competition in the semiconductor industry. International competition in high technology links technological progress, economic performance, and national security problems in novel combinations. The object of the current study is to consider rigorously the alternative policy objectives--and the instruments to implement them--the US might employ in enhancing its competitiveness in this area.

This project is being conducted by Carl Kaysen and Charles Ferguson, who recently completed a doctoral dissertation on US/Japanese competition in semiconductors and computers. The topic has attracted widespread concern on the part of industry and government; the project is sponsored by Motorola and the Semiconductor Research Corporation.

This project reflects the high priority placed at the Center on understanding the forces that influence technological development in an era of international competition, to determine what an appropriate and feasible balance is for the US in technological leadership, and to suggest mechanisms from national, state, and industry perspectives for the US to achieve its technological potential. Research in this area at CTPID is designed to:

- *raise the level of national concern regarding the seriousness of the decline in US competitiveness and its implications for the economic vitality of the nation;

- *identify reasonable and achievable expectations for US technological leadership while recognizing that international competition is fundamentally healthy and that transfer of technology to less developed countries is desirable; and

- *understand what policies are necessary to foster, develop, and deploy technology that may enable the US to regain an appropriate technological position in the international community.

As are the research findings of the IMVP, the results of the current project on high technology are contributing to the work of the MIT Commission on Industrial Productivity.

Research Program in Communications Policy

Members of the Research Program in Communications Policy (RPCP) are pursuing interdisciplinary research and analysis of communications issues involving the interaction of technology and policy. The program is led by Professor Russell Neuman (Department of Political Science). The RPCP is conducting several research projects including a two-year project supported by the Markle Foundation to carry out a program of research on future developments in American telecommunications.

The program oversees the Audience Research Facility (ARF) located at the Liberty Tree Mall in Danvers. The facility recruits a demographically broad range of shoppers as study participants to conduct studies of audience responses to new developments in audio and video technologies. ARF combines the advantages of controlled laboratory conditions with access to samples of a size and diversity not usually available to

survey researchers. Current projects include work on alternative measurement techniques for assessing how people respond to media technologies and tradeoffs among them, the role of audio in the perception of television, political learning from broadcast news, interactive media and High Definition Television. These research projects are helping to develop new forms of data and new analytical tools to assist decision makers in reshaping the network structure.

RPCP research is conducted in cooperation with the Media Laboratory. Corporate sponsors include the Time-Mirror Co., International Communications Association, Bellcore, ABC, CBS, NBC, Time Inc., the Washington Post Co., and a consortium of broadcast companies associated with the Center for Advanced Television Study.

The goal of the program is to maintain a critical mass of high quality education and research, to offer interdisciplinary training to some of the best young talent in the field, and to add the viewpoint of independent and academically based scholarship to the public debate about issues of public communications. There are currently four faculty, five visiting scholars and research associates, 30 undergraduates (all UROP students) and 15 graduate students associated with the program.

Communications Forum

The Communications Forum links the Research Program on Communications Policy to companies affiliated with the Industrial Liaison Program (ILP). The Forum's major activity is a series of seminars. Between 15 and 20 meetings a year are designed to cover the full range of communications research at MIT. The scope of the Forum reflects the complexity and linkages within the field of communications. The speakers represent public and private sector interests as well as the research perspective. The presentations for the academic year 1987-88 included "Does Regulation Inhibit Entrepreneurship in Communications?", "Do the Media Choose the President?", "Art and New Technologies: Two Multimedia Speculations", "What is the Future for VSATs--Is it Bypass or More?", "Universal Broadband Telecommunications: The Big Gamble", "Learning Media and Learning Environments: Technology and Cognition", "Introducing ISDN: Some Users' Experiences", "New Issues in Children's Television", "Has Hypertext Come of Age?", "The Judge, the Telephone Industry and the FCC", "Technology, Pornography and Free Speech", "Industry/Technology/Art: New Readings of American Media", "The Politics of HDTV", and "Economic Approaches to Radio Spectrum Management".

Professor Harvey M. Sapolsky (Department of Political Science) was appointed the new Director of the Forum effective July 1, 1988. He is assisted by a Seminar Program Committee chaired by Professor Pierre Humblet. Funding for the Forum is provided by a portion of the ILP membership fees of companies sharing a special interest in communications policy and research.

Risk Assessment and Risk Management

Risk assessment and risk management are integral to the policy implications of many of the projects and programs in progress at the Center. Policy makers face an enormous challenge in trying to understand how risk assessment and risk management strategies should be integrated into decision making. MIT's strengths in science and technology can contribute greatly to these processes, but additional input from the social sciences is needed to broaden our understanding of how risks are perceived and how they can best be managed. Since its inception, the Center has promoted inquiry into the multifaceted interaction between technology and policy that in practice requires an understanding of risk. Research on hazardous substances and toxic waste management, environmental and occupational health, nuclear safety, and biotechnology are areas in which risks to human welfare must be considered.

This year a series of meetings were held to develop an agenda for studying risk management. The effort reflected faculty interest in identifying and profiling risks using risk assessment and developing risk management strategies, policies, and regulatory approaches. Participants and speakers at the meetings, which were held from September 1987 through May 1988 included faculty members from MIT and representatives from several other universities and organizations; many of the foremost theoreticians in the areas of risk assessment and management contributed to the process. Topics included approaches to the management of hazardous waste, the social amplification of risk, liability issues and the insurance crisis, and the responsibilities of multinational corporations to disclose risk. A published proceedings of the meetings is forthcoming.

This year, Dr. Dale Hattis has continued his work on improving quantitative risk assessment for chemicals posing a potential danger to health. His project on improving health risk assessment involves research into the use of pharmacokinetic models to improve health risk assessment for both cancer and other endpoints (including neurotoxicity and reproductive effects). Such models should allow better assessment of the "biologically effective dose" of activated metabolites delivered to target tissues by different external exposure levels, routes, and time patterns of exposure. They should also permit more appropriate translation of dose units among species.

In current work, the modeling techniques are being applied to carcinogenic risks of perchlorethylene (used in dry cleaning), male fertility and female embryo toxicity effects of glycol ethers (a widely used group of solvents used in paints and elsewhere), and neurotoxic risks of acrylamide. Dr. Hattis is participating as a member of the National Research Council's "Committee on Neurotoxicology and Models for Assessing Risk". The acrylamide case study will be incorporated into the committee's report. The project is supported by the US National Institute for Occupational Safety and Health, and the US Environmental Protection Agency.

A new effort that is expected to be undertaken this year will assess the occupational risks for health care workers of infection with hepatitis-B or the AIDS virus.

Law, Ethics, and Environment

Technology and law are the focus of several Center research projects supervised by Professor Nicholas A. Ashford. One new project is an investigation of "The Adequacy of Tort Law and Insurance in Preventing and Compensating Damage from Exposure to Toxic Substances". With co-investigators Charles Caldart, Esq. and Dr. Hattis, Professor Ashford is gauging the strengths and weaknesses of both legislative mandates for compensating for environmental impairment and traditional common law remedies in tort. The second new project being pursued by Professor Ashford with the assistance of Mr. Caldart and Dr. Hattis addresses "Community Monitoring for Exposure to Toxic Substances: Scientific, Legal, and Ethical Concerns". This research will examine the scientific basis for determining exposures, and the legal and ethical problems concerning the communication of risks to the public. The project is sponsored by the Centers for Disease Control. The CDC and the EPA are required under new Superfund legislation to monitor and register potentially toxic substances and take appropriate actions to inform citizens about them.

Professor Ashford and Dr. Hattis are also continuing their work on "Policy Issues in Regulation of Toxic Substances". They are examining a variety of strategic and policy issues in the testing and regulation of toxic substances. These include the problems of small volume and new chemicals, maintenance of innovation, complex and variable chemical substances, biotechnology, multimedia initiatives, and state-federal relationships.

Also in the area of public policy, Professor Ashford is studying "Technology, Innovation and Public Policy in the US", an analysis of various US government actions that influence technical change, innovation, and the adoption of new technologies. Through the project "Technology and Public Policy" he is examining mechanisms of government policy which influence technological change in industrial and developing nations.

Dr. Caroline Whitbeck and Professor Robert W. Mann are the principal investigators on the project "Engineering Innovations, Knowledge and Responsibility" designed to determine how selected medical technologies change knowledge and influence the lives and relationships of the parties who develop, use, and are affected by them. Of particular interest is the nature and extent of the responsibility of bioengineers. The objective of the project is to enable bioengineers, manufacturers, policy makers and others to foresee how their actions contribute to changing people's lives and relationships. The investigators will not only examine moral standards for responsible work in bioengineering, but will show how changes occur in those standards. The project is sponsored by the National Science Foundation.

Sponsored by the MIT Department of Physical Plant, Peter Cebon, a 1988 graduate of the Technology and Policy Program, investigated "Nontechnical Factors in University Energy Management". He asked why universities use more energy than might be predicted by economic and technical analyses and identified some real constraints on energy conservation. The study addressed the interplay of organizational and financial constraints as they affect design for new and refurbished buildings; component selection; systems analysis; preventative and urgent maintenance; explicit energy conservation and capital renewal projects; and the interaction of users with managers and with technology. Project findings contribute to understanding how large organizations deal with problems outside the organization's primary objectives.

Environmental Impact Assessment Review is a quarterly journal highlighting approaches to impact assessment, environmental decision making, and the resolution of environmental disputes. EIA is an area in which technological and policy factors must be coordinated in a timely and publicly acceptable manner. The journal is designed to give planners, engineers, scientists, and administrators at all levels of the public and private sectors insight into the multiple problems and processes of environmental decision making.

The Review provides a forum in which practitioners and scholars can share what they are learning about EIA and dispute resolution. Three issues a year include feature articles on a wide range of topics and also summaries of new forecasting techniques and breakthroughs in environmental decision making organized under eight departments: Generating Alternative Policies, Programs and Designs; Impacts on the Natural Environment; Social Impact Assessment; Presenting Technical Information; Decision Making; NEPA: Theory and Practice; International Perspectives; and AGENDA for Environmental Negotiation. One issue annually is devoted to a single topic of special interest. The special issue for 1987-88 illuminates several aspects of decision making for Superfund.

Many of the issues addressed in EIA Review are comparable and tangential to those being pursued by Center investigators. The refereed quarterly is directed by Professor Susskind (Senior Editor), Editor Teresa Hill, and an International Advisory Board. It is published and distributed internationally by the Elsevier Science Publishing Co. Inc.

EDUCATION

Technology and Policy Program

The Technology and Policy Program (TPP) educates men and women for leadership on the technological issues confronting society. The main degree offered by the Program is the Master of Science in Technology and Policy. With this diploma graduates can enter directly into practice in government and industry. The program also sponsors individual interdepartmental doctoral programs. These are designed for each student according to his or her particular interests. About one fifth of graduates choose to proceed to doctoral studies, and many do so at MIT.

TPP has now completed its first decade. There are now over 60 students in the program, with a strong contingent of women and minorities (about 25 percent). The quality of the students is outstanding, as reflected by the large number of distinguished fellowships and awards they receive from outside sources. This year for example: Steven Farber was awarded the 1987 Alumni Prize for Excellence and Leadership in Technology and Policy. Alice Outwater and Isna Soedjatmoko shared the 1987 Prize for Best Thesis in Technology and Policy. Roni Rosenberg and Peter Cebon were selected for the Alfred Keil Fellowship for the Wiser Uses of Science and Technology. Mr. Cebon also received the Marvin E. Goody Prize for the best MIT graduate thesis in building arts.

In May 1988, the Program received the Irwin Sizer Award for the Most Significant Improvement to MIT Education.

DANIEL ROOS

Introduction

Founded in 1973, the Center for Transportation Studies is an interdepartmental organization whose basic 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. It coordinates transportation activities at MIT and has developed programs of research, education, and industry outreach. These programs are supported in part by income from the Center's endowment, which was contributed by the UPS Foundation, and in part by support from industrial and government sponsors, private foundations, and from MIT.

MIT has a unique opportunity in the field of transportation, since it has faculty expertise in all the transportation modes (air, ocean, rail, auto, transit) and all the relevant disciplines (technology, systems analysis, planning, management, and the social sciences) for dealing with transportation issues. The Center for Transportation Studies adopts a multimodal, multidisciplinary approach, building upon existing capabilities in the academic departments to address significant urban, regional, national, and international transportation issues and problems.

The Center draws on the faculty of MIT to provide programs of interdisciplinary research and education. The vitality of the Center depends on its ability to attract faculty 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 the following departments affiliated with CTS.

School of Engineering

- Department of Civil Engineering
- Department of Mechanical Engineering
- Department of Aeronautics and Astronautics
- Department of Ocean Engineering
- Department of Electrical Engineering and
Computer Science
- Department of Materials Science and Engineering

School of Science

- Department of Mathematics
- Department of Physics

School of Humanities and Social Science

- Department of Economics
- Department of Political Science

Sloan School of Management

School of Architecture and Planning

- Department of Architecture
- Department of Urban Studies and Planning

In the last several years, the Center has built upon its strengths within the School of Engineering to expand its focus to include faculty from the other four schools of the Institute, particularly the Sloan School of Management.

The Center's Executive Committee, chaired by the Director, Professor Joseph Sussman, added Professor Jean Tirole of the Department of Economics and a specialist in industrial organization. Continuing members of the committee are: Professor Ralph Gakenheimer, Department of Urban Studies and Planning; Professor Thomas Magnanti, Sloan School of Management; Professor David Marks, Head, Department of Civil Engineering; Mr. Gerard McCullough, Deputy Director, Center for Transportation Studies; Professor T. Francis Ogilvie, Head, Department of Ocean Engineering; Professor Yosef Sheffi, Head, Transportation Systems Division of the Department of Civil Engineering; Professor Robert Simpson, Director, Flight Transportation Laboratory of the Department of Aeronautics and Astronautics; Professor Nigel Wilson, Department of Civil Engineering, and Chairman, Master of Science in Transportation Committee; and Professor David Wormley, Head, Department of Mechanical Engineering.

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. Focus areas outlined in the Center's Long Range Plan are:

- Logistics
- Information Systems
- Transportation Technology
- Infrastructure Development

During the past academic year, 97 sponsored, seed, and unsponsored projects were listed in the Center's **Current Research Projects in Transportation at MIT** (available upon request), 28 of which had been initiated within the past year. Categories of research, and the number of new projects in each:

- Infrastructure maintenance and rehabilitation (5)
- Computer systems (5)
- Air transportation (4)
- Logistics and network analysis (3)
- Rail and trucking (3)
- Health and safety (2)
- Ocean transportation (2)
- Urban and regional transportation planning (2)
- Motor vehicle (1)
- Labor issues (1)

Annual research volume for the Center continued at the healthy level of \$2.2 million.

Seed Research

CTS has a seed research fund which permits faculty and staff members to develop new and innovative research ideas. This past year, support was made available for the following programs:

Professor Henry Marcus	The Development of a Research Agenda in Transportation of Hazardous Substances
Professor Tomasz Wierzbicki	Crashworthiness Aspects of Safe Transportation of Hazardous Substances
Professor Harilaso Koutsopoulos	New Information Technology for Transportation Systems

Seed projects have historically been a mechanism to position CTS for important new thrusts. The above efforts will allow CTS to pursue several important new areas.

In addition, the Center is committed to pursuing research in advanced highway technology as part of a national effort to utilize information systems, guidance and control, vehicle systems, etc., to enhance the capacity and safety of our highway systems. Professor Sussman serves on the Mobility 2000 Steering Committee which helps set research directions for an integrated national program.

Research Highlights

Professor Stuart Madnick and Dr. Amar Gupta of the MIT School of Management completed a major study of distributed, heterogeneous data base systems and their applications to transportation and logistics. The research was performed for the U.S. Air Force through the U.S. Department of Transportation's Transportation Systems Center. A comprehensive eight volume set of reports was produced.

The New England Transportation Infrastructure Consortium, headed by Mr. Thomas Humphrey of the Center, completed its first round of projects, has begun its second set, and is planning for its third. This consortium is led by MIT and includes the state universities of Massachusetts, Vermont, Maine, New Hampshire, and Rhode Island. It is funded by the state Departments of Transportation of those five states. A substantial project on sensing concrete bridge deck deterioration through infrared thermography and ground penetrating radar, headed by Dr. Kenneth Maser, is part of this program.

Professor Yossi Sheffi continued his logistics program with support from the Burlington Northern Railroad and North American Van Lines to examine various network operations issues in rail and trucking.

Professor Tomasz Wierzbicki continued his multi-company crashworthiness research consortium, which added Volvo, Saab, and Fiat as members.

The AAR Affiliated Lab at MIT, directed by Professor David Wormley and managed by Mr. Carl Martland, developed new programs in track maintenance and wear, and utilizing expert systems in freight car fleet maintenance.

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 largest of the graduate programs is the Master of Science in Transportation, an interdepartmental program administered by the Center since its inception in 1979. This year, the program graduated its 100th student. These students 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. We were gratified to see a qualitative improvement and quantitative increase in applications for this program for the upcoming year.

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 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 for particularly able students at the MST and doctoral levels funded by the UPS Foundation. For 1987/88, the doctoral award was split between Paul Thompson and Scott Smith, and a special summer fellowship was granted to Brian Cromwell. In 1988/89, we again split the UPS award between Rina Rotshild and Takayuki Morikawa and made a special half fellowship award to Jonathan Richmond.

In addition, for 1987/88, we awarded partial fellowships to two particularly able MST students, Mark Hickman and Ibrahim El Sanhoury. For 1988/89, an MST fellowship was awarded to Theodore Botimer.

Further, we continued to provide partial support for needy graduate students in transportation.

INDUSTRY AFFILIATE ACTIVITIES

The CTS Industry Affiliates Program, established in 1981 to develop relationships between MIT and the transportation industry, is an important component of the education and research programs of the Center. The program is under the direction of Mr. Gerard McCullough, Deputy Director of the Center. This year, in welcoming six new members, the program grew by 40 percent, bringing the total membership to 21 firms. The new members are: American President Lines, Conrail Corporation, Dow Chemical Company, Federal Express, Johnson and Johnson, and Nabisco Brands.

Continuing members of the program are Burlington Northern Railroad, CSX Transportation, Digital Equipment, DuPont, General Motors Research Laboratories, Gillette, IBM, 3M, Norfolk Southern, Rockwell International, Ryder System, Sea-Land, Southern Pacific Transportation, Union Pacific, and United Parcel Service.

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 year, nearly 50 members and guests convened in November for a meeting sponsored by the CSX Transportation Company, held in part on a train from Baltimore to Philadelphia.

The subject of the meeting was Quality in Transportation. Because of the widespread perception that American products have lost some of the quality that once made them famous--and because of the growing recognition that to remedy that, American manufacturers must not only make a quality product, but must also get that product delivered on time and in good condition--this year's meeting brought manufacturers and carriers together to consider the concept of quality in transportation and how best to achieve it. Mr. R. D. Sanborn, then President of CSX Distribution Services and currently President of Conrail, spoke on quality issues in transportation, and presentations were made by Ms. Renee D. Rysdahl, Vice-President of Quality, CSX Transportation; Professor N. Venkatraman of the Sloan School of Management, and Professor Yossi Sheffi of the Department of Civil Engineering at MIT.

Ryder System will host next year's meeting in December 1988, which will focus on transportation partnerships.

Transportation Forum

Over the past several years, as part of the Affiliates Program, the Center has sponsored a series of forums attended by top decision makers from some of the nation's leading carriers and shippers, and from government, to help define emerging issues in the transportation sector and to build a consensus for coping with them.

Last October, the fourth in that series was held at MIT's Endicott House. It focused on The Transformation of Industrial Relations in the Transportation Sector, a trend which is leading to increased joining together of management and labor interests in the industry. Organized and chaired by Sloan School Professor Robert McKersie, co-author of The Transportation of American Industrial Relations, the meeting brought together more than 30 key people in the management and labor forces of the air, rail, and trucking sectors to consider how these changes can best be brought about. Participants included Mr. Gerard Grinstein, the Vice Chairman of Burlington Northern, Mr. W. John Swartz, President of the Atchison Topeka and Santa Fe, and Mr. Clifford Sayre, Director of Logistics at DuPont.

Summer Executive Program

For the fourth consecutive year, an intensive one-week seminar taught by Professor Yossi 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. This program is an integral component of the CTS Affiliates Program.

Technical Seminars

For the second year, as part of the Affiliates Program and in conjunction with the Operations Research Center, the Center sponsored a two-day technical seminar on Recent Developments in Mathematical Programming. Attended by nearly 60 representatives of the corporate sector, the seminar offered practitioners an up-to-date account of the latest techniques in optimization, with

an emphasis on logistics, and provided participants with opportunities to share their experiences from the field. We plan to make this an annual event focusing, in alternate years, on optimization and stochastic systems.

The Transportation Computing Lab (TCL)

The Transportation Computing Laboratory (TCL) is the focal point of education and research computing in transportation and serves faculty, staff, and students. Under the direction of Professor Yossi Sheffi, the TCL has been in great demand this past year. A variety of applications in logistics, demand modeling, infrastructure, and other areas, have been developed for use in both our 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.

During this past year, to provide a quality service to our transportation students and faculty, we added various hardware and software. We purchased an IBM PS/2 Model 50, two AST Research Premium/286, and a DELL/286 machine. In addition, we have purchased 80286 accelerator cards for two of the IBM XT machines. Also, we have purchased our first 80386 machine--an IBM PS/2 Model 80. This system was purchased with a 115 mb hard disk and with the IBM 8514/A monitor and graphics card. Software obtained included statistical analysis packages, compilers, data base management software, spreadsheets, graphics software, AI software, and applications development packages.

We plan for continued growth of the TCL and aspire to providing a state-of-the-art facility for transportation research and education.

SPECIAL EVENTS

A Transportation Retrospective. In November 1987, over 250 people attended a CTS sponsored seminar to examine transportation decisions made 15 years ago in Boston which continue to have an important effect on the lives of those who live here. In November 1972, Massachusetts Governor Francis Sargent announced his decisions as to which highway and transit facilities would be built in the Boston region, decisions which have formed the basis of the transportation construction agenda since that time.

To evaluate those decisions with hindsight, a panel was convened--made up of the people who played important roles in those decisions. These included Mr. Jack Wofford, then Director of the Boston Transportation Planning Review, now a lawyer in private practice; Ms. Ann Hershfang, then representing the League of Women Voters of Boston, now State Undersecretary of Transportation; Professor Tunney Lee, then representing Cambridge, now Head of the MIT Department of Urban Studies & Planning; Professor Alan Altshuler, then State Secretary of Transportation, now Professor in Harvard University's Kennedy School of Government; and Mr. Fred Salvucci, then Transportation Advisor to Mayor Kevin White of Boston, now state Secretary of Transportation. The public was invited to attend and offer their comments. With the current emphasis on the depression of the Central Artery in Boston, this debate on urban transportation planning was quite timely for the local professional community. A lively discussion ensued which continued late into the evening. The Center's Tom Humphrey took a leadership role in organizing the program.

Symposium

The Tenth International Symposium on Transportation and Traffic Theory was held at MIT from July 8th through July 10th, 1987, with support from the Center for Transportation Studies and the National Science Foundation.

This series of symposia has, over the 29 years since its inception, become the preeminent international assembly of transportation scientists. This was the first time in 16 years that the symposium had been held in the United States, the last one having been at the University of California at Berkeley in 1971.

Papers representing research from nine different countries encompassing North America, Europe, Asia, and Australia were presented. Over 100 attendees contributed to a lively symposium with extensive discussion of all the papers. The symposium, which was chaired by Professor Nigel Wilson of MIT and Professor Nathan Gartner of the University of Lowell, was dedicated to Robert Herman of the University of Texas, the founder of the symposia series.

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 not only of students and faculty from the Institute, but also of representatives from the Transportation Systems Center of the U.S. Department of Transportation, from other universities, and from business and research organizations in the area. Speakers during the year were: Dr. Michael Meyer, Massachusetts Department of Public Works; Mr. Joseph Tranfo, United Parcel Service; Professor Robert Simpson, Department of Aeronautics and Astronautics, MIT; Mr. Peter Cook, Louis Berger International, Inc.; Mr. David J. Hughes, Bangor and Aroostook Railroad; Mr. William Spreitzer, General Motors Research Laboratories; and Mr. R. Thomas Lagow, United Airlines.

Summer Subjects

Last August, for the fifth consecutive year, a one-week summer course was offered by Professor Nigel Wilson in Public Transportation Service and Operations Planning. The session drew 20 participants from public transportation authorities in Asia, Latin America, and Europe, as well as Canada and the United States.

Gifts

The UPS Foundation continued its financial support of the Center. In addition to the already established endowment, the Foundation made a special gift for a project in urban congestion, to be headed by Professor Nigel Wilson.

CTS received a one-year grant from the Santa Fe Southern Pacific Foundation and a three-year commitment from the Norfolk Southern Foundation. Both are designated as unrestricted funds to be used at the Center's discretion.

A very generous personal gift from Denman McNear, Chairman and Chief Executive Officer of the Southern Pacific Transportation Company and Chairman of the Center's Advisory Committee, has established the "McNear Transportation Fund," to support seed research activities.

The transportation world continues to be an exciting environment in which to work. Change is the order of the day. Changes in government-private industry relations, changes in technology ranging from robotics to expert systems to materials science and changes in international markets make the world of transportation a particularly challenging theatre. With its multidisciplinary faculty, CTS is well positioned to contribute in the transportation areas, and we look forward to this opportunity with great anticipation.

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 in 1963 as Project MAC (for Multiple Access Computer and Machine Aided Cognition), the Laboratory developed the Compatible Time Sharing System (CTSS), one of the first time shared systems in the world, and Multics -- an improved time shared system that introduced several new concepts. These two major developments stimulated research activities in the application of on-line computing to such diverse disciplines as engineering, architecture, mathematics, biology, medicine, and management. Since that time, the Laboratory's pursuits have expanded, leading to pioneering research in knowledge based systems, computer networks, and public cryptography. Today, the Laboratory's research spans a broad front of activities, grouped in four major areas.

Research in the first and largest area entitled Machines, Languages, and Systems strives to discover and understand computing systems at both the hardware and software levels that open new application areas and/or effect sizable improvements in their ease of utilization and cost effectiveness. A large part of the Laboratory is involved in the architecture of large multiprocessor systems (which tackle a single task, e.g., speech understanding or weather analysis) by the Computation Structures, Real Time Systems, Information Mechanics, and Parallel Programming Research Groups. Continuing research includes the analysis and synthesis of languages and operating systems for use in large geographically distributed systems by the Distributed Systems and Programming Methodology Groups.

The second major area, entitled Intelligent Systems, involves making programs more intelligent by capturing, representing, and using knowledge which is specific to a narrow problem domain. The Laboratory's Clinical Decision Making Group uses expert medical knowledge for computer-assisted diagnosis, and members of the Laboratory's Theory Group are involved with learning systems research.

The Laboratory's third principal area of research, entitled Theory, involves exploration and development of theoretical foundations in computer science. For example, the Theory of Computation Group strives to understand ultimate limits in space and time associated with various classes of algorithms; the semantics of programming languages from both analytical and synthetic viewpoints; the logic of programs; the utility of randomness in computation; concurrent computation and the links between mathematics; and the privacy/authentication of computer-to-computer messages. Other examples of theoretical work involve the study of distributed systems by the Theory of Distributed Systems Research Group and the links between randomness, cryptography, and knowledge.

The fourth area of research entitled Computers and People, is concerned with the interrelationships between people and machines -- for example, the societal impact of computers carried out by the Societal Implications Research Group.

Some of the year's research highlights were as follows:

The Tagged-Token Dataflow multiprocessor architecture has moved on to the design and construction of the Monsoon Processors. A meeting with industrial partners has disclosed several companies interested in collaborating with us in this effort. The resultant one gigaflops (peak performance) 256-processor-machine will be driven by a comprehensive software system, Id World, which has been documented, released, and is continuously being improved.

In the same area of multiprocessor systems, we are continuing our research on: Project L (Professor Stephen Ward) and CAM-8 (Dr. Tommaso Toffoli). L is a new model of computation characterized by: (1) a large collection of finite state machines and state representations with the property that programs written in object-oriented languages (with concurrency) can be efficiently compiled into L structures; and (2) L structures can be efficiently executed on a proposed hardware architecture associated with the L project. The CAM-8 architecture is a highly parallel cellular automaton machine that builds on our previous CAM machines and further extends our architectures in this area. This machine is currently being proposed for construction.

Project Mercury, the Laboratory's kingpin of distributed systems research, is aimed at facilitating the composition of programs across different computational environments; for example, a program written in a Lisp Machine environment should be able to call a program written in C under a Unix environment. Mercury is currently under implementation with demonstrations expected next year.

The Laboratory's Learning Systems program strives to develop theories and machines that can learn from their environments and not from their programmers. Substantial work involving both the LCS and AI Laboratories has led to a first workshop in this area during Spring 1988.

Two of the Laboratory's past accomplishments have continued to achieve higher levels of standardization. First, the NuBus standard (Professor Stephen A. Ward), adopted by Apple Computer for Macintosh II and by Texas Instruments for their Explorer, has led to numerous new peripherals that can attach onto these buses. Second, the X-standard (Mr. Robert W. Scheifler) for graphics has been placed in an industrial consortium within LCS. This consortium, which has over 20 full-time corporate members and over 100 corporate users of X, maintains and evolves the X-standard.

During 1987-1988, the Laboratory has continued its successful Distinguished Lecturer Series with presentations by William Poduska, Chairman and CEO of Stellar Computers, Inc.; Raymond Kurzweil, Chairman of the Board of Kurzweil Applied Intelligence, Inc.; Ralph Gomory, Sr. Vice President and Chief Scientist of IBM Corporation; Alfred Aho, Head of Computing Principles of the Research Department of AT&T Bell Labs; and Jeffrey Ullman, Professor of the Computer Science Department of Stanford University.

This reporting period brought the following new Laboratory members: Drs. Jon Doyle, David Kranz, Norman Margolus, and Mr. John Wroclawski as Research Associates; Professors Jacob Katznelson, Janet Kolodner, Butler Lampson, Nancy Leveson, and Eva Tardos as visiting faculty; and Professor Anant Agarwal as Assistant Professor. In addition, the Laboratory had several promotions, including Professors Arvind and John Guttag and Associate Member Stuart Madnick to Full Professors; and Professor William Weihl to Associate Professor.

Our Laboratory consisted of 332 members -- 45 faculty and academic research staff, 45 visitors and visiting faculty, 70 professional and support staff, 122 graduate and 50 undergraduate students -- organized into 16 research groups. Laboratory research during 1987-88 was funded by 11 governmental and industrial organizations, of which the Defense Advanced Research Projects Agency of the Department of Defense provided over half of the total research funds. Also during the same period the Laboratory employed 21 undergraduates through the LCS UROP Summer Studies Program (formerly Hacker Heaven) which strives to identify promising potential researchers in computer science.

Technical results of our research in 1987-88 were disseminated through publications in the technical literature, through Technical Reports (TR 395-TR 425), and through Technical Memoranda (TM 333-TM 362).

MICHAEL L. DERTOUZOS
DIRECTOR

Laboratory for Electromagnetic and Electronic Systems

The Laboratory for Electromagnetic and Electronic Systems (LEES) is a coalition of 15 faculty and 12 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 Electric Utilities Program.

POWER ELECTRONICS

The growing interest and activity in power electronics is illustrated by the formation this year of the IEEE Power Electronics Society. Professor J.G. Kassakian is its first President, and Profs. Schlecht and Verghese are active in various Society roles.

Professor Verghese has taken the lead in organizing the first Technical Committee, on Computers in Power Electronics, under this newly formed IEEE Power Electronics Society. He is also the Chair of an IEEE Workshop on this topic being held at MIT in August, 1988.

MIT's Summer Session offering of 6.33s, Introduction to Power Electronics, taught by Professors Kassakian, Schlecht and Verghese, has almost doubled in enrollment (42) this year as compared to any previous year. A workshop on the design of magnetic energy storage components for power electronics applications was held this spring. This was part of the MIT/Industry Power Electronics Collegium, which continues to be a source of support and guidance for the power electronics activities.

Professors J.G. Kassakian, M.F. Schlecht, and Mr. D. Otten direct their efforts toward the development of small, component-like power supplies. These micro-supplies are seen as leading the next revolution in power supply architectures for computers and in automotive power distribution systems. Projects aimed at the development of very high power density, mass-producible power supplies have led to the design of an advantages 10MHz topology and identified component needs that have focused attention on achieving specific improvements in component fabrication techniques. Using the high resolution capabilities of the Microsystems Technology Laboratories, power MOSFET structures with very small parasitic capacitances and an integral gate driver that avoids the parasitic inductance of an external connection have been designed. Magnetic structures have been designed to be small, efficient, and mass-producible. Active filters that provide the strict filtering requirements imposed by the FCC and VDE agencies have been designed and constructed that effectively make inductors and capacitors appear 500 times larger.

During the past year, progress toward new integrated analog and digital control and drive circuitry capable of the high speed, high bandwidth requirements of 10 MHz power supplies has been demonstrated by the fabrication of CMOS circuits through the MOSIS program. In the laboratory, these have been shown to have significantly better performance than control and drive circuits currently available. Efforts are underway to develop improved versions in a BICMOS process.

The installment in the MTL Facility of a newly developed thick film hybrid process based on inexpensive yet highly conductive copper conductor parts has made it possible to develop a working prototype of a 50W, 40V-5V power supply operating at 5MHz with an efficiency of 85% and a power handling density (without the heatsink) of 100W/in³. Current technology is at 25W/in³.

Prof. G.C. Verghese and his students have presented novel control possibilities for power electronic circuits. These include using digital controllers that implement unconventional control laws such as periodically varying output feedback, designed using sampled-data models. Control laws for multi-switch, multi-output switched power converters have been developed for the first time using a modern multivariable control approach. Nonlinear control schemes with guaranteed large-signal properties have also been presented. This work has grown out of a focused effort to expose fundamental circuit-theoretic properties of switched power circuits and to study modern nonlinear control ideas in the context of such circuits. The effort continues with increased funding from industry.

SYSTEMS IDENTIFICATION AND CONTROL

Research carried out by Professors Lang, Thornton and Verghese, and Dr. Umans and their students integrates electromechanical actuators and sensors with power electronics and digital controllers using modern estimation and control algorithms. The research is as much concerned with the interactions between systems components as it is with the components themselves. Industrial sponsors are close partners in the research, often sending representatives to facilitate technology transfer. Results of previous work have been incorporated into products. This research continues to be a catalyst for several undergraduate and graduate classes.

The 60-kW drive based on the variable reluctance motor (VRM) which was previously described has now been tested at a commercial laboratory. All tests of electrical and mechanical variables matched predictions. In terms of efficiency, the device is competitive with induction and permanent magnet machines while being significantly lower in cost. This work continues to foster considerable industrial interest in other VRM-based applications. As an example, last year Professor Lang reported the development of a VRM-based drive suitable for robotic applications. Key to that work was a nonlinear controller that regulated a smooth torque at all speeds. The resulting device can now be purchased commercially. With the objective low cost and high efficiency, another VRM-based drive was reported last year that was aimed at appliance-type applications.

The need for an explicit position sensor on VRM's was eliminated by using a filter with the controller which could estimate the rotor position from electrical terminal variables alone. This approach has been refined so that estimates are within 0.1% of an electrical cycle. This approach is being extended to permanent-magnet and induction motors. Models have been used to show sufficient accuracy for not only propulsion and appliance applications, but for robotics and manufacturing as well. As experiments in our laboratory progress, technology transfer to the industrial sponsor is already underway.

Micromotors, which are to be "machined" from silicon to have rotors on the order of 100 micrometers in diameter, are being investigated by Professors Lang and Schlecht. This work is being carried out in close collaboration with Professor Senturia of the Microfabrication Center, who replaces Professor Howe on this project. Analytical models have been used as a guide to playoffs between fabrication constraints and performance. During the last months, mechanically free rotors have been fabricated that can be rotated with a probe tip.

A failure analysis project has been initiated to prevent, predict and detect failures in that order in rotating machines. The prevention is by avoiding stressful operation, the prediction by keeping track of such abnormal operation and watching for signs of damaging change, and the detection by using parameter and state estimation techniques using models that include failure mechanisms. Typical failures would be in the bearings, the cooling system and in the rotor and stator windings. So far models have developed that appear attractive for broken rotor bar detection on induction machines.

The potential for parameter and speed estimation in induction machines, using only measurements of stator voltage and current, has been demonstrated in recent work of Professor Verghese and his students. Their two-level scheme estimates parameters at a slow time scale and speed at a faster time scale. Work on improving the accuracy and robustness of the scheme, as well as on real-time implementation, continues. In joint work of Professors Verghese, Lang and one of their students a control theory approach has been used to precisely characterize "ideal" electrical machines, which are those amenable to the celebrated Blondel-Park transformation. Efficient perturbation methods for periodically varying models have been developed to evaluate the stability of machines that are nearly ideal.

ELECTROMECHANICS, HEAT-TRANSFER, AND CRYOGENICS

The experimental activity on the 10 MVA superconducting generator project, carried out by Professors Kirtley, Smith and Wilson, Dr. Umans and Mr. Hagman has focused on a cryogenic problem. Tests and supporting analysis has led to the discovery of a fabrication error which resulted in bypassing of cryogenic fluid around one of the thermal isolation torque tubes. Repair of this leak has resulted in a substantial improvement in performance. The rotor can now be filled with liquid helium and has been instrumented to measure the temperature distributions during cooldown and low temperature but stationary operation. The information gathered will be valuable in future designs of thermal isolation struts and current carrying leads.

The possibility of using the still-developing "high T_c" superconducting materials in generators has been investigated by Professors Kirtley and Smith. The results to date indicate that ceramic superconductors have a long way to go before they will be competitive with metallic superconductors operating at liquid helium temperatures. The studies also indicate that superconducting generators will be economically competitive with conventional machines, even in the relatively small 200 to 300 MVA unit sizes.

As part of a program for the United States Navy, Professor Kirtley has been studying aspects of electric power distribution systems. An effort to build accurate and reduced order models of switching power converters has laid the framework for making predictions about stability and response of networks of these converters.

CONTINUUM ELECTROMECHANICS

In an EPRI sponsored project co-supervised by Professors J.R. Melcher and M. Zahn, electrokinetic effects on flow electrification is 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 delivery systems. A compact laboratory apparatus and charge sensor have been developed that provide measurement of properties needed to predict charge generated by a transformer oil/cellulosic interface under both equilibrium and non-equilibrium conditions.

Whether for laboratory studies or for the monitoring of equipment in the field, the instrumentation challenge is to distinguish between the amount of charge entrained in the liquid without the instrumentation and signals caused by generation of charge by the monitor itself. To this end, an "Absolute Charge Sensor" (ACS) has been developed and successfully tested. It is being patented and will be provided to other EPRI contractors to measure the electrification tendencies of various power apparatus components, such as pumps, radiators, and cooling ducts, in other laboratories and in field tests.

The paper "AC Corona Charging of Particles" by Ph. D. student R.M. Ehrlich and Professor Melcher was given a Prize Paper Award by the IEEE Industrial Applications Society.

The "imposed omega-k" approach to the determination of complex permittivity distributions, developed previously by Professor Melcher and his students, has now been embodied in a commercial apparatus which has been shown to resolve water distributions in salt-water ice.

HIGH VOLTAGE AND INSULATION RESEARCH

Funded by a consortium of electric utility organizations as part of the MIT Electric Utility Program, Professor Zahn and his students continue to be concerned with non-invasive electro-optic measurements of the electric field distribution in high voltage stressed materials. The motivation of this work is to understand electrical conduction and charge transport phenomena in order to reduce losses and raise the electrical breakdown strength of electric power apparatus. This year they have improved the sensitivity of the measurement technique to perform measurements in polymers, sulfur hexafluorid (SF₆) and transformer oil, typical "work-

horse" materials used as high voltage insulation. This is the first time such measurements have been made in these materials at high field levels used in practice. New results have also been obtained at low field strengths. Whereas prior approaches have typically worked in the field range of 100KV/cm, by adapting a technique developed elsewhere, measurements can now be performed at field levels as low as 100V/cm. They have successfully carried out sensitive charging transient measurements in transformer oil and in heated polyethylene with current work also testing liquid nitrogen for possible applications to superconducting cables. Early measurements have shown a field enhancement at each electrode due to heterocharge accumulation of ions in the fluid volume being attracted to counter charges on the electrodes.

In a project conducted with Mr. K.A. Wright and Dr. C.M. Cooke, Professor Zahn has documented the effects of electron beam energy and current density on electron penetration into polymethylmethacrylate (PMMA) to generate peak fields up to 3.5 MV/cm. Particular motivation is to understand the "electrical tree" discharge patterns often found in solids, especially for power cables. Videotapes of the charging and discharging process provide a complete history of the electric field build-up and collapse.

To further improve the efficiency of optical data acquisition and processing, an optical multi-channel analyzer (OMA) expert system has been developed. Whereas past electro-optic field mapping measurements used photographic film which had to be analyzed manually, the OMA system reads in the light intensity over a two-dimensional array of photodiodes and automatically converts the light signals to electric field and charge distributions. Whereas film data could only be read from the location of light minima, the OMA system can be quantitative about the gray scale between the dark fringes. The system is being used to study the field and charge distributions in high voltage stressed highly purified water. A particular focus is to empirically determine the charge injection boundary conditions at the electrodes.

Professor M. Zahn has served as Guest Editor of the IEEE Transactions on Electrical Insulation for a special issue on Flow Electrification on Electric Power Apparatus.

Dr. C.M. Cooke and Mr. K.A. Wright have been developing an acoustic method to measure volume distributed space charges in solid dielectrics. By using acoustic signals at 30 megahertz and above and improved deconvolution processing of data, improved spatial resolution has been demonstrated.

The Transformer Monitoring and Trend Analysis (TMTA) Program managed by Dr. C.M. Cooke, has been jointly carried out by Professors J.R. Melcher, F.C. Schweppe, J.L. Kirtley and Mr. W.H. Hagman, Mr. D.P. Flagg and Mr. E.P. Warren and a number of graduate and undergraduate students. Organized through the Energy Laboratory Electric Utilities Program, this project has been funded by a consortium of electric utilities.

The TMTA Program has centered around the development of a pilot facility consisting of a small, highly instrumented 50 kVA transformer. Mr. Hagman managed both the hardware and computer systems developments on this facility. Fundamental to the project is the UNIX based system that has been developed for the organization and processing of information. This system is designed to preserve the modularity necessary for implementation flexibility while allowing for the interaction between modules necessary so that models used to distinguish between normal and abnormal behavior can incorporate data from the other modules. The structure for this system was strongly influenced by Professor Schweppe, who foresaw the use of model parameters identified from dynamic data as the first of two trend analysis levels.

During the past year, emphasis has been put on five sensor-modules; thermal, water-in-oil, gas-in-oil, vibrations and partial discharges.

The project has now reached a stage where the sponsor emphasis is on transfer of some of what has been accomplished to a commercial group. This group is committed to the field testing and further development of a prototype.

BIOLOGICAL ELECTROMECHANICS AND PHYSIOLOGY

Professor R.C. Lee and his group are investigating the underlying mechanism of transduction which explains the sensitivity of normal fibroblast to electric fields. They have recently demonstrated that a calcium dependent intracellular step in the biosynthetic process is altered by applied 10 Hz, 1.0 $\mu\text{A}/\text{cm}^2$ sinusoidal electric current. They have also recently discovered that the production of collagen messenger RNA is depressed by this current.

Progress continues to be made in studying changes in cell membrane transport properties in response to strong electric fields. Membrane disruption by strong electric fields may have an important role in the tissue destruction which follows electric shock. Publications based on this work were recently awarded the James Barrett Brown Award of the American Association of Plastic Surgeons for "significant advances in the field of Plastic and Reconstructive Surgery". Recent discoveries include the first demonstration of irreversible electroporation in intact muscle tissue and first demonstration of reversible electroporation in isolated muscle cells.

Professor Grodzinsky and his group have been studying the effects of mechanical and electrical forces on the repair and degeneration of connective tissues. Recent experiments using cartilage in organ culture have led to the discovery that biosynthesis of extracellular matrix macromolecules can be enhanced or depressed by dynamic compression at specific frequencies and amplitudes. These in vitro studies have been motivated by the natural electromechanical properties of cartilage, characterized extensively by the Grodzinsky group. The results may be useful in optimizing therapeutic strategies that are currently used to stimulate cartilage growth and remodeling in vivo.

Cartilage degradation has proved very difficult to detect at the earliest stages when clinical intervention might delay or prevent the cartilage degeneration associated with osteoarthritis (OA) and eventual joint replacement. A newly funded initiative is aimed at the development of a probe for nondestructive surface detection of early OA degeneration. The probe is based on the group's previous discovery that small electric currents will induce a measurable mechanical stress in the tissue, proportional to the content of matrix proteoglycans (PG). The loss of these PG molecules is one of the earliest events in OA.

Another recent program involves the development of a cartilage cell culture system to enable further exploration at the individual cell level of the physical and biological mechanisms by which mechanical forces and electrical currents may regulate cellular behavior. This collaboration with the Biochemistry Department at Rush Presbyterian Medical Center, Chicago, is also aimed at the development of a cartilage-like tissue material.

Professor Grodzinsky is also continuing research on electrically controlled gel membranes for protein separations and on-demand drug delivery. Four distinct mechanisms for controlling solute flux can now be combined to elicit significant, controlled changes in protein flux. These include electromechanical deformation of the membrane, electrophoretic and electroosmotic augmentation of protein flux, and electrostatic partitioning of charged proteins into the membrane. A model combining electrochemical and electromechanical equations of motion has been found to predict the kinetics of certain aspects of electrical modulation of membrane swelling and transport properties. This combination of theory and experiment is essential to enable optimization of process control.

The work of Professor M.L. Gray and her students is directed towards understanding the mechanisms by which connective tissue growth, development, and remodeling are influenced by mechanical forces. Current initiatives include work supported by NSF to examine the effect of compressive stress on mandibular condyles grown in vitro. In work more directly focusing on mechanical transduction mechanisms in cartilage, she is pursuing a preliminary discovery, which she reported in the *Jnl of Orthopaedic Research* (with A.M. Pizzanelli, A.J. Grodzinsky and R.C. Lee) that compression-induced changes in mobile ion concentrations is linked to the alterations in cell synthesis observed during physiological compression.

In collaboration with co-workers at Beth Israel Hospital, Professor Gray is developing 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.

In cooperation with the Lahey Clinic, Mr. K.W. Wright has continued his radiotherapy work, using high energy x-rays and electrons. Treatment planning, dosimetry and implementation of these plans has been undertaken, including the design and fabrication of apparatus for unusual situations. The radiotherapy department at Lahey is adding a new 6 MeV linear accelerator and this addition requires the move of the Van de Graaff electron beam unit. Mr. Wright is coordinating and carrying out the necessary work to enable these moves.

UTILITY SYSTEM PLANNING AND OPERATION

The overall effort in this area has been led by Professor F.C. Schweppe and Dr. R.D. Tabors. It has been motivated by the large changes that are taking place today in the electric utility industry of the United States and throughout the world.

Development and application of system planning techniques for decision making involving multiple attributes, multiple decision makers, and massive uncertainty have continued. Work on a pilot study which will, hopefully, be a precursor for a major investigation of the future of electric power in New England is nearing completion. The same techniques have also been applied to design of power distribution systems.

In one major demand side management effort, Mr. D. Flagg has been instrumental in helping the continued evolution of the appliance signature technique which enables monitoring of individual appliance usages within a house by observing currents and voltage at the service box. Investigations into extending the concept to the commercial sector have started. A second demand side related project involves the development of strategies, logic and concepts for microprocessor based residential control of appliances in the presence of a spot priced based energy market place (the price of electricity fluctuates hour by hour to track the actual cost of production and delivery). A book on the spot pricing of electricity will be published by Kluwer Press this summer.

A variety of papers at various levels of technical detail have been written related to the ever broadening national discussions on wheeling and deregulation of electric power systems. The thrust of our efforts has been to help the controversial debates center on the real issues by defining them clearly, comparing the advantages and disadvantages of the approaches, and providing analytic tools which can be used to determine which of the many paths should be followed.

Visiting Professor Marija Ilic, who has been the recipient of the First NSF Presidential Young Investigator Award, is continuing her research towards understanding the dynamics of voltage/reactive power phenomena of utility systems subject to unusual power flows. This area, neglected in the past, has become a cause of major concern in preventing system-wide blackouts. The voltage problem is recognized by the New England System, as well. Professor Ilic is currently working on an EPRI sponsored project which sets the basis for automation of voltage monitoring and control and promises to be the first of this kind in the United States.

One motivation for Professor Ilic's visit to MIT was to relate voltage performance of power systems to the energy cost, in collaboration with Professor Schweppe...who tragically died of a heart attack on July 8, 1988.

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 Uses of Bandwidth in Single Mode Fiber Optic Local and Metropolitan Communication Networks

This project of Professors Pierre Humblet and Robert Kennedy is part of the recent MIT-NYNEX collaborative research agreement. Professor Humblet and Kennedy will seek to determine the best use of transmission bandwidth in single mode fiber optic local and metropolitan communication networks with a view towards eliminating the need for certain switching functions. This could reduce the cost of handling information and allow greater speed and flexibility. The NYNEX agreement provided for substantial support to set up a laboratory to experiment with fiber based communication systems.

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 worm C. elegans, 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.

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.

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 and both point-to-point and broadcast communication channels are of concern. Some of the topics in this area are multiaccess communication processes, routing, flow 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 in 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; Control; Mathematical Foundations of Machine Intelligence; Distributed Information and Control Systems; Algorithms and Architectures; and Experimental Program. CICS has a postdoctoral and visitors program in support of its research program. A number of outstanding graduate students are appointed Graduate Fellows. Speakers in the 1987/88 CICS Colloquium Series included: Karl Astrom, Lund Institute of Technology, Lund, Sweden; Stephen Grossberg, Center for Adaptive Systems, Boston University; Robert C. Berwick and Silvio Micali, MIT; Persi Diaconis, Harvard University; and Brian D. Ripley, University of Strathclyde, Glasgow.

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 and 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 Local Communication Networks

The goal of this recently initiated program is to identify and resolve the fundamental issues pertaining to the design of local communication networks that utilize very broad and optical fiber technology to realize an integrated system that can provide all necessary communication services in a campus environment. Theoretical, experimental and design activities contribute to the work.

Particular emphasis will be placed upon taking full advantage of the unique capabilities of single mode fiber technology. For example, the use of fiber couplers to increase the number of users that can be accommodated without repeaters will be investigated. Another effort will explore the use of tunable optical lasers and frequency selective detection to achieve dynamic frequency concurrency. Professors Robert Kennedy and Pierre Humblet are conducting this research.

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, 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, problem 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. These investigations involve the application of theoretical, analytical, and experimental techniques in areas such as information and computer science and technology, computational linguistics, and psychological human-factor studies.

Several current projects center on analytical and experimental investigations of expert computerized intermediary systems to assist end-users in accessing and operating heterogeneous bibliographic database and retrieval systems. Expert assistance requires mixed-initiative (computer and human directed) actions to develop for any problem a conceptual formalization followed by an interactive process of search strategy formulation, execution, evaluation, and modification. Staff members who have supervised these efforts include Mr. Richard S. Marcus and Professor J. Francis Reintjes.

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 judgement. 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.

HIGHLIGHTS

Among the speakers in the LIDS Colloquium Series were Dr. Andrew Viterbi of QUALCOMM, Inc., and Professor Karl Astrom of the Lund Institute of Technology, Lund, Sweden, and Professor Eugene Wong, Chairman, Department of Electrical Engineering and Computer Sciences, University of California at Berkeley.

Professor Lena Valavani was promoted from Assistant to Associate Professor of Aeronautics and Astronautics. She was also reappointed Associate Editor of the IEEE Transactions on Automatic Control.

Dr. Alexander H. Levis was elected a Fellow of the IEEE for applications of system and control theory to complex-decision making processes. Dr. Levis served as President of the IEEE Control Systems Society for 1987 and is serving as Vice-Chairman of the Technical Board of the International Federation on Automatic Control (1987-1990). Dr. Levis gave the keynote address on "Human Organizations as Distributed Intelligence Systems" at the new IFAC Symposium on Distributed Intelligence Systems in June, 1988.

Professor Sanjoy Mitter was elected to the National Academy of Engineering. He was one of the organizers of the 1988 Summer Program on Signal Processing at the Institute for Mathematics and Its Applications, Minneapolis. Professor Mitter was invited to speak at the "Calculus of Variations and Stochastic Processes" Conference in honor of Professor W.H. Fleming and at the Third International Workshop on the Bellman Continuum, INRIA, Sophia-Antipolis, France.

The book "Parallel and Distributed Computation: Numerical Methods" by Professors Dimitri Bertsekas and John Tsitsiklis will be published in August by Prentice-Hall.

Among the visitors in residence at LIDS this year was Alberto L. Sangiovanni-Vincentelli, Professor of Electrical Engineering and Computer Sciences at the University of California at Berkeley and an internationally recognized authority on VLSI Computer-Aided Design Tools. Professor Sangiovanni-Vincentelli was on sabbatical at MIT's Department of Electrical Engineering and Computer Science and was accompanied by a number of his graduate students.

Professor Shankar Sastry, Department of Electrical Engineering and Computer Sciences, University of California at Berkeley, was also on leave at LIDS.

ROBERT G. GALLAGER
SANJOY K. MITTER

Laboratory for Manufacturing and Productivity

The Laboratory for Manufacturing and Productivity (LMP) is an Engineering School Lab addressing the science and technology of production. While it grew out of a Department of Mechanical Engineering group of longstanding, it is now a broad, multidisciplinary group whose backgrounds range from applied mechanics and materials, through to control systems design and artificial intelligence. The LMP continues to derive its support from many diverse funding sources, with more than half coming from private industry. This makes for a unique environment where the equal mix of government and industry sponsors allows a longer term perspective to evolve alongside a more goal oriented, industrially relevant viewpoint. However, the lack of a sustained, broadly based funding source has prevented the forging of stronger collaboration within the lab, and within the Institute. One hope for the new "Leaders for Manufacturing" program is that it can help increase such vital working relationships.

The LMP currently comprises the work of over 70 graduate students, 15 faculty (coming from Civil Engineering, Mechanical Engineering, Materials Science and Engineering and Electrical Engineering), one Senior Research Scientist, one Principal Research Scientist, and several post-doctoral associates. Our use of UROP students is also quite high, with typically over 30 undergraduate joining in our research programs per year. We as well take primary responsibility for supervision of a technical instructor staff of three and for a lab machinist. Professor David Hardt serves as Director, Professor Steven Dubowsky as Associate Director, and Ms. Sally Burns is Assistant to the Director for Collegium Affairs.

Activities in the lab are supported by individual research agreements with 20 industries, as well as 15 grants and contracts from the US Department of Energy, Office of Naval Research, National Science Foundation and the Army Materials Lab, and the Defense Advanced Research Projects Agency. In addition, we have three active research consortia, the MIT/Industry Composites-Polymer Program (with 6 member companies), the Tribology Research Program (with 3 members) and the newly established Knowledge Systems Program (with 2 members).

Beyond the individual research contacts, the LMP-Industry Collegium maintains a strong information liaison with its member companies through meetings, newsletters, research reports and a library of faculty publications. With over 40 members (which includes the research sponsoring companies), the Collegium serves to present the total picture of our diverse research programs. Income from the Collegium is used primarily to promote novel research activities, including student fellowship support.

Personnel Changes

After spending the past two years bringing young faculty into the Lab, this year we added to the senior ranks. Professor Nam Suh, founder and former Director of the LMP returned from his three year term as Assistant Director of the NSF for Engineering. Nam brings back his brilliance and insight as a manufacturing researcher, but now augmented with national policy experience that is so vital to our still evolving approach to manufacturing education and research.

The Lab was also fortunate to have Dr. Stanley Gershwin join us as a Senior Research Scientist. Stan returned to full time status at MIT after a year as a visiting Professor at Boston University, and a part-time Principal Research Scientist in the Lab for Information and Decision systems. Stan is a pioneer in the area of control theory applied to manufacturing systems problems, and greatly adds to our new efforts in this area.

Faculty Research

Research in the LMP falls roughly into five categories: Manufacturing Processes, Flexible Automation, Tribology, Manufacturing Systems, and Design/Manufacturing Integration. Many of our faculty and staff work in several of these areas, and we expect such cross disciplinary work to increase as the field of manufacturing research matures.

In the process area of our research, Professor Tim Gutowski's MIT-Industry Composite and Polymer Processing Program is the single largest effort. Through this consortium of companies with common problem in such processing, a variety of research has continued, ranging from detailed analyses of resin - fiber interaction during part consolidation and in-process control of resin curing, to integrated studies of flexible automation in composite processing. The change in name of this program (with the addition of "Composite") signifies the new focus of this program under Tim's leadership.

Professor Nam Suh, since his return this January, has been concentrating on his longstanding interest in Design Theory, and has produced both a graduate subject and textbook in Axioms for Design. Nam is also participating in the Composite and Polymer Processing Program, and is as well continuing his work in novel methods for metal alloying and casting.

Professor Ming-Kai Tse has begun a new program in "tribo-acoustics", which seeks to marry the various sources of information generated when surfaces interact into a powerful Non-Destructive Evaluation (NDE) tool. This work is concentrating not only on how to sense these interactions, but also optimal fusion of the information into a test of product or process quality.

In the area of process optimization and control, Professor Ely Sachs has been studying VLSI production, and has applied new concepts of process modeling and optimization to reduce variability. This off-line, open-loop form of process control will soon be augmented with "chip-level" process control. Ely has also begun work in collaboration with the Material Processing Center, on the optimization of processing for high temperature superconduction materials.

Professor Ernie Rabinowicz, along with Dr. Nanniji Saka, have continued in their leadership of the Tribology Research Program. Their work encompasses many forms of tribology ranging from conventional mechanical bearing friction, wear, and failure studies to similar work on more exotic material systems. In particular, there is currently a strong interest in the tribology of magnetic recording media.

Professor Dave Hardt has continued his work in control of processes, and recently demonstrated the used of adaptive, multivariable methods in welding, which greatly improved process performance. The long awaited "Variable Configuration Die Forming Press" (internally dubbed the MIT PRESS) has come on line and is being used to form one of a kind sheet metal parts without fixed tooling. Professor Hardt, in collaboration with Profs. Chryssosstomidis, Eagar and Moshaiov has been part of a new effort in Design and Manufacturing Integration for Ship Building, wherein common production processes will be simulated for design purposes.

Professor George Chryssolouris continues to build his program on laser machining. A twin 800 watt laser system was developed this year that allows fine positioning of multiple beams, thereby permitting exploration of this large scale machining concepts. Turning of both simple shafts and spiral has been demonstrated on metals, polymer composites and ceramics. George has also been active in the manufacturing system area, with develop of a software system for manufacturing decision making (MADEMA). He has as well used the systems concepts laid down there to examine novel methods for machine tool control, in this case concentrating on information extraction from multiple sensors.

Professor Steven Kim has begun to build the Knowledge System Program, and has been exploring uses of AI in manufacturing system decision making, process control and manufacturing/design integration. These various activities all center around the ambitious goal of developing a sound mathematical base for a science of manufacturing.

Dr. Stan Gershwin, who joined the LMP this year, has been pursuing work in the control of manufacturing systems. In particular, Stan is concerned with real-time scheduling or demand tracking. Starting from simple demand and production process models, Stan has now build his concept to the point where various demand models can be tracked and process complexities are being introduced. Much of this work has been pursued in conjunction with the Microsystems Research Center.

Professor Harry West has launched new research in two areas, as well as continuing his work on braced manipulators. In a related area he has become concerned with improved task programming for robots, this related to improving the task performance ease for actual manipulators. Harry has also joined in an effort to create a design-manufacturing tool for enhanced CAD, wherein the designer can add process simulation to the existing geometry and structural analysis tools.

Professor Kamal Youcef-Toumi continues his vigorous research in manipulator design and control. While remaining very active in the direct drive robot area, Kamal has recently developed a new theory for control systems with unknown dynamics, which appears to be a powerful means for controlling certain classes of non-linear systems typical of many manufacturing operations. He has as well continued his work in flexible fixturing based on CAD data combined with robotically configured flexible tooling.

Professor Steven Dubowsky has continued his work in 3D interferometry for part measurement. This novel means of metrology incorporates simple commercial vision systems with custom produced fringing masks the latter produced directly from a CAD database.

David E. Hardt

Leaders for Manufacturing Program

MIT has long offered educational and research programs for advancing the manufacturing industries. In addition to its sizeable efforts along these lines in the engineering departments and the School of Management, MIT has established several major interdepartmental laboratories. From this base, and with the recognition that the new world standards of productivity and competition are adding new dimensions to what a university might contribute to the discipline of manufacturing, faculty from the Schools of Engineering and Management developed over a four-year period a framework for discovering new manufacturing paradigms. Key starting points are the facts that the program is a) a 50-50 partnership between the Schools of Engineering and Management; b) a partnership between MIT and select group of manufacturers; and c) a teaming of disciplines in both teaching and research.

The Leaders for Manufacturing Program, which began in the spring of 1988, is a five-year experiment to discover the principles for "manufacturing science," a holistic approach to manufacturing which begins with research and development and product/process design and continues through production, sales, and service. These diverse features, which must be integrated into the knowledge base for operating future manufacturing firms, are rich in unknowns about technology, management, and human behavior. The challenge for the Leaders Program is to fully utilize the diverse intellectual and physical resources available through MIT's departments, laboratories, and centers, and those of the Industrial Partners.

Two groups provide oversight and advice: the Governing Board consists of senior executives of the nine Partner companies (Alcoa, Boeing Company, Digital Equipment Corporation, Eastman Kodak Company, Hewlett-Packard Company, Johnson & Johnson, Motorola, Inc., Polaroid Corporation, and United Technologies) and leaders from MIT; the Operating Committee consists of executives from the nine Partner companies and senior faculty in the Program. The importance of these two groups to the Leaders Program cannot be overstated; their critical functions become increasingly apparent as the vision for the Program becomes clearer.

Over thirty MIT faculty in the two Schools have become involved in the startup phase of the Program, which will eventually establish fourteen term professorships and ten to fifteen junior faculty grants to assist faculty in developing new approaches to teaching and research in this field. Additional resources to faculty and staff will also become available, selections to be reviewed, and ideas to be encouraged through the frequent input of the Governing Board and Operating Committee.

One phase of the graduate education effort is the Fellows Program. The first twenty Fellows began an intensive 24-month program June 1, 1988; another twenty will be selected for the program beginning in June, 1989. All Fellows must have engineering or physical science degrees and demonstrated leadership potential, and must have been accepted into MIT by meeting the normal graduate admission requirements. During the 24-month study/research period, the Fellows are fully supported and take a structured set of subjects in management and one of the engineering disciplines to complete degree requirements in both management and an engineering department. The masters thesis is based on research carried out by the student, who spends six months as part of a student team at a manufacturing site of one of the corporate Partners. The purposes of such an experience are manifold: it provides opportunities to learn how to work on complex problems as part of a multidisciplinary team, to discover concepts and principles that will underpin the new manufacturing paradigm, and to gain access to people and facilities unlike those available on campus. Research projects begin during the 1988-89 academic year.

Subjects developed for the Fellows Program and the knowledge gained from the research, which is organized and supervised by MIT faculty in collaboration with the Partners' engineers and managers, will be fundamental to the educational materials developed, which will initially be suited to the masters degree level, though the intent is to impact undergraduate education later on.

Additional research sponsorship through the Program will allow more masters and doctoral students to conduct research either on campus or using the resources of the committed Partners; the Program will eventually support approximately seventy graduate students.

H. KENT BOWEN
THOMAS L. MAGNANTI

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 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 9 percent of the MPC's total budget, with 30 percent provided directly by industry, and another 61 percent from government agencies.

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 control 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 low-gravity-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 (DMSE), Mechanical Engineering, Electrical Engineering and Computer Science (DEECS), and Chemistry.

A more detailed description of research activities can be found in the *Materials Processing Center Report 1987-1988*. This book is available from the MPC headquarters in Building 12-007.

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 industrial 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, the Materials Synthesis Laboratory (MSL), combines the talents of experts in electronic structure theory, inorganic synthetic chemistry, crystal chemistry, and materials science to understand in greater detail bonding and crystal chemistry; eventually they hope to predict and synthesize entirely new families of solids that exhibit novel properties. The MSL joins five previously organized consortia: the Ceramics Processing Research Laboratory, the Laboratory for the Processing and Evaluation of Ceramic and Metal Composites, 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.

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.

Last year, the MPC began an innovative program to expose high school students to the rewards of basic scientific research and engineering here at MIT. Outstanding science students from Massachusetts high schools 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 scientific career, preferably at MIT.

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 six summer scholarships to sophomores and juniors enrolled in physics, chemical 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 87/88 academic year, the MPC offered six fellowships to students in the Departments of Materials Science and Engineering, Chemical Engineering, and Electrical Engineering and Computer Science.

The undergraduate summer scholarship and the graduate student fellowship programs are now linked by a new initiative that grants up to a three-year, full fellowship to the very best of our undergraduate summer scholars. The first such fellowship was awarded this year to Miss Chrysanthe Demetry, who will begin her graduate studies this fall with Professor Yet-Ming Chiang.

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 practising engineers and scientists from industry. Symposia held last year dealt with "Surface Modification of New Materials" (in cooperation with Osaka University, Japan), "Vapor Phase Processing of Electronic Materials," "Advanced Electrical and Optical Materials: Fabrication, Characterization, and Optimization," "Emerging Materials and Processes" (in cooperation with the Industrial Liaison Program), "On-Line Control of Materials," and "Processing and Evaluation of Metal and Ceramic Matrix Composites."

Last year, the MPC signed a friendship agreement with The Welding Research Institute (WRI) of Osaka University to encourage complete reciprocity in academic exchange and cooperation. The WRI is much broader than the name implies: with over 75 percent of its research directed toward materials processing, the WRI is a close counterpart to MPC, both in terms of its research interests and its close affiliation with industry. This exchange, which signifies the growing commitment of Japan to foster a two-way exchange of information, provides the MPC with an access to ongoing advanced materials processing research in Japan.

The MPC, through its direct interaction with industrial personnel, promotes the technology transfer upon which innovation in materials processing is based. For the past eight years, the MPC has provided a focus and forum in which academic, industrial, and government personnel can broaden their knowledge while collaboratively developing new scientific and technological skills in materials processing. Through such collaboration and cooperation, we expect to exercise our leadership role in the evolution of new materials, the development of the processing technologies required to manufacture with these materials, and, ultimately, to transfer materials processing know-how into the worldwide marketplace.

R. M. LATANISION

SCHOOL OF HUMANITIES AND SOCIAL SCIENCE

This year the major focus of the School of Humanities and Social Science (SHSS) was on curricular development and change. The major initiatives of the School related to the changes in the Humanities, Arts, and Social Science Distribution (HASS-D) System and the establishment of a new HASS minor.

During the Spring of 1987 the MIT faculty voted to establish a new distribution system within the HASS component of the General Institute Requirements. Under the old Humanities Distribution (HUM-D) system, students were required to take three distribution subjects from a list of 23 categories, with a total number of approximately 150 subjects. In contrast, under the new HASS-D System students must still take three distribution subjects, but the number of categories has been reduced to five (Literary Studies; Language, Thought, & Value; The Arts; Historical Studies; Cultures & Societies) and the number of distribution subjects has been reduced to approximately 60. 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 will begin in the fall of 1988 and is 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 coming year, there will be 17 new subjects in the HASS-D system, with a total of 57 subjects. By the time it is fully phased in (AY 1991-92), it is hoped that the HASS-D System will consist of entirely new subjects or existing subjects that have been subject to major revisions.

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), last spring the MIT faculty voted to institute a HASS minor, which consists of six subjects in an approved HASS field, one of which must be an Institute-wide elective. The HASS minor will be available to all students, effective the academic year 1988-89. Fifteen minor fields are currently approved, and we expect that the HASS minor will prove to be an attractive option to MIT undergraduates.

It should be noted that a number of curricular changes also occurred in the graduate area. Of these, the most notable was the establishment of a new Ph.D. program in the History & Social Study of Science & Technology, which is jointly offered by the faculties within Anthropology, History, and the Program in Science, Technology, and Society. This will begin in the academic year 1988-89. This program is particularly significant, since it represents the first establishment of a graduate program within the humanities fields that have not previously had any graduate program. As such, we hope that it will serve as a precursor to a number of small graduate programs within the humanities that complement MIT's intellectual strengths.

The faculty within the School of Humanities and Social Science garnered an impressive array of honors and awards this year. Of these, the most notable were Institute Professor Robert M. Solow's receipt of the Nobel Prize in Economics for his work in the theory and measurement of economic growth and productivity; and Institute Professor Noam A. Chomsky's receipt of the Kyoto Prize in Basic Science for developments in linguistic theory. In addition, Institute Professor Morris Halle of the Department of Linguistics and Philosophy was elected to the National Academy of Science, while Professors Oliver D. Hart of the Economics Department and Professor Heather N. Lechtman of the Anthropology/Archaeology Section were elected to the American Academy of Arts and Science. Guggenheim awards were made to Professor Hart, Professor Jean Tirole of the Economics Department, Professor Pauline R. Maier of the History Faculty, and Associate Professor Jeanne S. Bamberger of the Music and Theater Arts Section. In addition, grants from the National Endowment of the Humanities were received by Professor Maier, Assistant Professor Rita B. Goldberg of the Literature Section, and Assistant Professor Sarah Deutsch of the History Faculty. Associate Professor Peter Perdue of the History Faculty received MIT's Edgerton Award for outstanding contributions on the part of a junior faculty member, and Associate Professor Philip S. Khoury of the History Faculty received the George Beer Prize in European Intellectual History.

The resource development activities of the School of Humanities and Social Science have been particularly strong this year. New grants from the Mellon, MacArthur, and Luce Foundations have enabled the School to undertake a number of new initiatives and to strengthen its academic programs. In this connection, I would like to note the contributions made by Barbara G. Stowe, Assistant Dean for Resource Development. We wish her well in her new role as Director of Foundation Relations within MIT's Resource Development Department and note that her loss to the School will be substantial.

This year has seen a number of administrative changes within the School, with the following resigning from their role as Section Head: Professor Claire J. Kramsch of the Foreign Languages & Literatures Section; Professor Maier of the History Faculty; and Professor John H. Harbison of the Music and Theater Arts Section. We will miss their insights and administrative wisdom, but wish them well as they return to a professional life focused on scholarship and teaching.

Ann F. Friedlaender

TABLE I

Enrollment in Humanities, Arts, and Social Science Subjects:
1987-88

Field	Elective Subjects		Distribution Subjects		Totals	
	<u># of Subjects</u>	<u># of Students</u>	<u># of Subjects</u>	<u># of Students</u>	<u># of Subjects</u>	<u># of Students</u>
Anthropology/ Archaeology	10	98	6	206	16	304
Economics	17 ³⁹	1153	2	39	19 ⁴¹	1192
Foreign Languages & Literatures	44 ⁶⁹	925	26 ³⁹	578	70 ¹⁰⁸	1503
History	13	139	19	625	32	764
History of Art & Architecture	2	12	3	239	5	251
Interdisciplinary	2	38	1	10	3	48
Linguistics	1	11	2 ⁴	122	3 ⁵	133
Literature	23	320	22 ³³	740	45 ⁵⁶	1060
Music	19 ²⁴	425	10 ²⁹	453	29 ⁵³	878
Philosophy	15	269	7	364	22	633
Political Science	26	320	10	393	36	713
Psychology	9	788	0	0	9	788
Science, Technology, & Society	8	45	5	124	13	169
Theatre & Dance: Performance	7 ⁸	79	0	0	7 ⁸	79
Traditions & Texts	0	0	4 ⁶	143	4 ⁶	143
Urban Studies	4	14	4	77	8	91
Visual Arts & Design	18	321	1	14	19	335
Writing	25 ³⁴	421	8 ¹⁵	275	33 ⁴⁹	696
TOTALS	243 ³⁰⁵	5378	130 ¹⁸⁴	4402	373 ⁴⁸⁹	9780

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.

CONCENTRATIONS IN ALL FIELDS OF HUMANITIES,
ARTS, AND SOCIAL SCIENCES *
JUNE 1988

Fields of Concentration	Class of 1991	Class of 1990	Class of 1989	Class of 1988	Totals in Fields
American Studies	(0) 0	(0) 0	(3) 2	(10) 10	(13) 12
Ancient and Medieval Studies	(0) 0	(0) 0	(4) 1	(6) 4	(10) 5
Anthropology/Archaeology	(0) 0	(3) 0	(6) 1	(8) 5	(17) 6
Economics	(0) 0	(13) 4	(88) 25	(224) 198	(325) 227
Film and Media Studies	(0) 0	(1) 0	(5) 0	(7) 5	(13) 5
Foreign Languages **	(6) 0	(30) 7	(99) 39	(179) 160	(314) 206
History	(0) 0	(14) 1	(46) 12	(90) 86	(150) 99
History of Art and Architecture	(0) 0	(0) 0	(5) 0	(8) 8	(13) 8
Labor in Industrial Society	(0) 0	(0) 0	(0) 0	(0) 0	(0) 0
Latin American Studies	(0) 0	(0) 0	(1) 0	(3) 3	(4) 3
Linguistics	(0) 0	(0) 0	(10) 4	(8) 1	(18) 5
Literature	(0) 0	(8) 0	(41) 8	(81) 80	(130) 88
Music	(0) 0	(29) 2	(67) 15	(111) 102	(207) 119
Philosophy	(0) 0	(2) 0	(25) 12	(58) 48	(85) 60
Political Science	(0) 0	(3) 1	(36) 16	(47) 41	(86) 58
Psychology	(1) 0	(11) 1	(54) 19	(133) 111	(199) 131
Russian Studies	(0) 0	(1) 0	(1) 0	(0) 0	(2) 0
Science, Technology, and Society	(0) 0	(1) 0	(10) 3	(8) 8	(19) 11
Theatre Arts	(0) 0	(2) 0	(3) 1	(6) 2	(11) 3
Traditions and Texts	(0) 0	(0) 0	(5) 0	(8) 9	(13) 9
Urban Studies and Planning	(0) 0	(0) 0	(2) 1	(6) 3	(8) 4
Visual Arts and Design	(0) 0	(3) 0	(11) 1	(35) 27	(49) 28
Women's Studies	(0) 0	(1) 0	(4) 1	(10) 8	(15) 9
Writing	(0) 0	(8) 0	(31) 0	(48) 39	(87) 39
Special Concentrations	(1) 0	(5) 3	(23) 9	(31) 32	(60) 44
TOTALS	(8) 0	(135)19	(580)170	(1125) 990	(1848)1179

* 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	(4) 0	(13) 3	(37) 11	(67) 60	(121) 74
German	(0) 0	(4) 1	(18) 10	(35) 30	(57) 41
Russian	(1) 0	(2) 1	(8) 6	(21) 22	(32) 29
Spanish	(0) 0	(6) 1	(16) 4	(32) 28	(54) 33
World Literature in Translation	(0) 0	(0) 0	(1) 1	(4) 5	(5) 6
Other Languages	(1) 0	(5) 1	(20) 7	(19) 15	(45) 23

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>
1974-75	63	48	1	14	126
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

* As registered in the second term of academic year 1974-75 to 1987-88. 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.

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>
1974-75	114	53	95	262
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

* As registered in the second term of academic year 1974-75 to 1987-88 (including special graduate students). Data taken from the Registrar's fifth-week report.

Humanities, Arts, and Social Sciences Office

The Humanities, Arts, and Social Sciences (HASS) Office underwent several personnel changes during the past year. In August, Professor Travis Merritt left his position as Director and Susan Mannett, Administrative Assistant, left in January due to the decentralization of the Course XXI Office. Ruth Spear assumed some of the Directorship responsibilities and remained Coordinator.

HUMANITIES, ARTS, AND SOCIAL SCIENCES INFORMATION AND SERVICES CENTER

The growth in student and faculty use of the HASS Office continued on about the same level as in the previous year. More students have greater concerns about their entire HASS program and fulfilling the Institute HASS Requirement and greater numbers seem to be using the office as a resource. Looking ahead it is probable that the office will see even more use because of the new HASS-D system and establishment of the HASS Minor Programs.

HASS Enrollment Statistics by Field and Subject -- Recent Trends

Year-by-year enrollments over the past four years show a modest decline in the overall number of students taking HASS subjects. In 1983-84 the total was 10,468 and in 1987-88 the total is 9,780. There has also been a correlating drop in the number of autonomous sections offered by HASS fields of 563 in 1983-84 to 489 in 1987-88. Enrollments in elective subjects show the greatest decrease of 6,076 in 1983-84 to 5,378 in 1987-88 with a sectional loss of 359 to 305. Distribution subject enrollments and section offerings show slight decreases, but remain around the 1987-88 numbers of 4,402 and 184 respectively. Individual field statistics which bear noting are those of Foreign Languages and Literatures which has had a steady decline in enrollments over the past four years of 1802 to 1503 and a decline in the number of sections offered of 125 to 108. Enrollments and section offerings in the Program in Science, Technology, and Society have been cut in half over the past four years. The 1983-84 enrollments of 409 with 31 sections are, in 1987-88, 169 and 13 respectively. Another trend worth noting is an increase in the Writing Program enrollments, without sectional increases, after a three year decline.

HASS Concentrations: Patterns of Popularity

The order of popularity in the fields of concentration has not changed since last year with Economics at the top followed by Foreign Languages and Literatures, Music, and Psychology. Although the overall number of students choosing Economics as a concentration has declined over the past three years, the field still remains the most popular with 325 proposed concentrators. Foreign Languages and Literatures follows with 314, Music at 207, and Psychology with 199 proposals. An examination by the Committee on HASS Majors, Minors and Concentrations may eliminate some of the fields of concentration that have had few students for a number of years.

Harvard Cross-Registration

Applications for Harvard subjects remain relatively stable with 171 students taking 182 subjects. The field of History has had a steady increase over the past four years with this year showing the greatest growth of 13 more applications than last year's total of 18. Subjects are taken in 32 different fields with almost half of them in foreign languages that are not offered at MIT.

COURSE XXI

In an effort to allow individual Humanities sections and programs to assume full responsibility for advising their respective majors, the Course XXI Office was phased out during the academic year.

The decision to phase out the Course XXI Office gives the same responsibility to the sections and programs that historically has been standard procedure in the School's full departments such as Political Science and Economics. The phaseout is also a natural result of the curricular and administrative reorganization which the School of Humanities and Social Science is undertaking in light of the new HASS initiatives such as the HASS Minor Programs, which are expected to attract significant numbers of undergraduates and which will be administered by HASS departments, sections, and programs.

Professor Philip S. Khoury, Associate Dean of the School of Humanities and Social Science, in cooperation with Susan Mannett, formerly of the Course XXI Office and now the Assistant to Dean Friedlaender for Personnel Administration, has been overseeing the transition process and serving as the faculty coordinator for interdisciplinary majors in Humanities. Ms. Mannett continues in her role as "resource person" for the Humanities sections and programs as they adjust to their new responsibilities.

Students

The May 1988 combined enrollment in XXI, XXI-E, and XXI-S was somewhat lower than last year (110 as compared to a May total of 135 in 1987). The distribution of these students into the ten available humanistic fields followed the same pattern as last year, with Literature and Writing still dominant, followed closely by History and Music.

Degrees

Four students received their S.B. in September 1987 (one in XXI and three in XXI-E), seven in February 1988 (two in XXI, two in XXI-E, and three in XXI-S), and 35 in June (13 in XXI, 15 in XXI-E, and seven in XXI-S), a total of 46 for the academic year.

Honors and Awards

Among the more notable distinctions and honors achieved by Course XXI students this year were:

Phi Beta Kappa: Seth Brown, Elliot Douglas, Tracy King, Gail Sadlo

Burchard Scholars: John Buck, Kenneth Goodson

Karl Taylor Compton Award: Seth Brown

Peter J. Eloranta Fellowship: Michael McIntosh

Jerome and Laya Weisner Award: Samuel J. Friedmann

Writing Prizes: Cynthia Closkey, Samuel J. Friedmann, John Hasemeyer, Pradeep Jeganathan, Michael McIntosh, Mathew Rita, Carol Waldmann, Corinne Wayshak

Women's Studies Writing Prizes: Pradeep Jeganathan, Michael McIntosh

PHILIP S. KHOURY

INTRODUCTION

The event of the year was the award of the Nobel Prize in Economics to Institute Professor Robert M. Solow. The Nobel prize was awarded for Professor Solow's contributions to the theory of economic growth, but that is only one of several fields in which he has made fundamental contributions. Professor Solow, who came to MIT in 1950, is widely regarded as one of the leading teachers in economics and is warmly admired within the Economics Department as a supportive colleague, as well as an outstanding scholar.

The vigorous scientific activity of the Department continued this year as well as energetic contributions to a wide range of economic policy discussions in a number of countries. A Department committee designed the undergraduate minor program in economics and other committees continued to review and revise undergraduate courses.

After a review of new candidates for junior positions, one such appointment was made. There was also a comprehensive review by the Department of its five year planning horizon to determine the requirements for maintaining its pre-eminent position.

FACULTY PERSONNEL

The appointment of Roland Benabou as Assistant Professor was made after an extensive review of the field of new candidates. Professor Benabou, who obtained his Ph.D. from this Department, has been at Centre d'Etudes Prospectives d'Economie Mathematique Appliquee a la Planification in Paris. He is an economic theorist, specializing in fundamental issues related to macroeconomics.

Professor James Poterba was promoted from Associate Professor. Professor Stanley Fischer was granted leave from the Department to assume the position of Vice President for Development Economics and Chief Economist at the World Bank. Professor Peter Temin assumed Professor Fischer's appointment as Associate Head of the Department. Professor Paul Krugman was on leave this year at the National Bureau of Economic Research.

There were several distinguished visitors to the Department this year including Elhanan Helpman, Professor of Economics at Tel Aviv University and Eliana Cardoso, Associate Professor at the Fletcher School of Law and Diplomacy. Professor Peter Howitt of the University of Western Ontario was among the visitors as well as Dr. Joseph Ramos of the U.N. Economic Commission for Latin America and Professor James Mirrlees of Nuffield College, Oxford University.

GRADUATE STUDENT RECRUITMENT AND ENROLLMENT

The competition among leading economic departments in admitting new graduate students was more intense this year, with some shifts in the foci of rivalry. The Department admitted 33 students for the academic year 1988-89, a slightly larger class than in the past. Of these, seven hold National Science Foundation fellowships. There will be 14 foreign students in the new class, of which five are fully supported by grants from institutions of their own countries.

The total number of graduate students enrolled has remained approximately constant. There are currently 105 graduate students in residence and 19 non-resident thesis writing students.

FACULTY RESEARCH

Faculty research continues at an intensive pace on a wide range of issues. The following are examples of faculty research: "An Incomplete Contracts Approach to Bankruptcy and the Optimal Financial Structure of the Firm," (Assistant Professor Philippe Aghion with P. Bolton); "Reaganomics," (Professor Olivier Blanchard); "Optimal Tax Theory and Development Policy," (Professor Peter Diamond); The World Debt Problem: Anatomy and Solutions, (Professor Rudiger Dornbusch); "Prospects for Development Finance in India," (Professor Richard Eckaus); "Job Duration, Seniority and Earnings," (Professor Henry Farber with K.G. Abraham); "Horizontal Mergers: Triage and Treatment," (Professor Frank Fisher); "Open-Loop and Closed-Loop Equilibria of Dynamic Games with Many Players," (Professor Drew Fudenberg with D. Levine); "Cheap Talk Can Matter in Bargaining," (Assistant Professor Robert Gibbons with D. Farrell); "Social and Economic Causes of Cancer," (Associate Professor Jeffrey Harris); "Incomplete Contracts and the Theory of the Firm," (Professor Oliver Hart); "Household Behavior and the Tax Reform Act of 1986," (Professor Jerry Hausman with Professor Poterba); "Asset Specificity and the Structure of Vertical Relationships: Empirical Evidence," (Professor Paul Joskow); "Housing Demand by the Elderly," (Professor Daniel McFadden); "The Relative Importance of Permanent and Transitory Components: Identification and Some Theoretical Bounds," (Assistant Professor Danny Quah); "Historical Perspectives and the Interpretation of Unemployment," (Professor Michael Piore); "Supply Responsiveness from the Existing Housing Stock vs. New Construction in Stratified Housing Markets," (Professor Jerry Rothenberg); "Licensing to Enhance Demand for New Technologies," (Assistant Professor Andrea Shepard); The Fall of the Bell System, (Professor Temin); The Theory of Industrial Organization, (Professor Jean Tirole); "Macroeconomic Aspects of Profit Sharing," (Professor Martin Weitzman); "The Cyclic Behavior of the National Office Market," (Associate Professor William Wheaton); "Some Invariance Principles and Central Limit Theorems for Dependent Heterogeneous Processes," (Assistant Professor Jeffrey Wooldridge with H. White).

FACULTY HONORS

The award of the Nobel Prize in Economics to Professor Robert Solow was widely approved among economists, not solely because of his professional reputation, but also because of his personal popularity. Other members of the faculty continue to participate vigorously in professional activities and to be recognized for their achievements. The following are only examples of such recognition. Professor Diamond was an Ida Beam Lecturer at the University of Iowa. Professor Dornbusch was invited to give the Hicks Lectures at Oxford University. Professor Fisher was the Invited Lecturer at the Australasian Meetings of the Econometric Society. Professor Fudenberg was elected as a Fellow of the Econometric Society. Professor Hart is a Council Member of the Econometric Society and received a Guggenheim Fellowship. He was also elected as a Fellow of the American Academy of Arts and Sciences and was the Fisher-Schultze Lecturer at the Econometric Society Meetings. Professor Poterba was awarded an Alfred P. Sloan

Fellowship. Professor Rothenberg was the recipient of the 1988 Graduate Student Council Teaching Award and Professor Tirole has received a Guggenheim Fellowship.

RESEARCH GRANTS AND NEW PROGRAMS

The faculty have received numerous grants to support their research. In addition several grants have been received to create or continue programs of research, teaching and support for graduate students. One of these is a grant from the Bradley Foundation for support of doctoral dissertations, research and workshops in the area of public economics, to be administered by Professor Poterba. A similar grant from the Sloan Foundation for the study of the U.S. in the World Economy is administered by Professor Dornbusch. The Ford Foundation has given a grant for industrial relations research and curriculum development to Professor Piore and another grant to Professor Tirole to complement the Pew Charitable Trust award in its Program for Integrating Economics and National Security.

The Sloan Foundation has made an unusual grant creating the Robert M. Solow Fellowship, to honor Professor Solow's many contributions to the profession and to the Sloan Foundation.

Richard S. Eckaus

Department of Humanities

Anthropology/Archaeology Program

The Anthropology/Archaeology Program, with two unfilled positions at the beginning of the academic year, devoted a great deal of time in 1987-88 running searches for an opening in cultural anthropology (joint with the Program in Science, Technology, and Society) and another in archaeology (joint with the Center for Materials Research in Archaeology and Ethnology). In both cases, the search led to the hiring of an outstanding scholar: Lisa Rofel of Stanford University, currently writing up a study of the Chinese silk industry, and Dorothy Hosler, a post-doctoral fellow at MIT's CMRAE, who has studied ancient Mexican metallurgy and is currently in the field investigating contemporary pottery in Ecuador. Both will join us in September 1989.

Anthropology/Archaeology is an enthusiastic participant in the new doctoral program in the social and historical study of science and technology, which was approved during 1987-88 and which will begin in September 1988. Professor Jean Jackson and Professor James Howe will teach in the first year of the new program, and Professor Howe is on its steering committee. In the area of undergraduate teaching, anthropologists are working up several Hass-D subjects, and we are renovating our teaching laboratory, under the supervision of Professor Heather Lechtman. Professor Arthur Steinberg has been named as the new head of the Integrated Studies Program, beginning in July 1988.

During the year, Program faculty carried on their long-term research projects---on Andean metallurgy (Professor Lechtman), Panamanian ethnohistory (Professor Howe), Venetian renaissance painting and its social context (Professor Steinberg); therapeutic community building in a chronic pain center and indigenous rights organization in the Colombian Amazon (Professor Jackson). At the time of the writing of this report, Professor Martin Diskin was in the field investigating the land reform program in El Salvador. Faculty members, with several books in process, published a number of articles during the year.

Among symposia attended, Professors Jackson, Diskin, and Howe all delivered papers at a conference at the University of Texas on "Nation-State and Indian in Latin America." Professor Diskin, in addition to a number of consultancies in the U.S., led fact-finding trips to Honduras and Nicaragua on behalf of Oxfam and the International Council of Voluntary Agencies. Professor Howe is contributing editor for Middle American Ethnology to the Handbook of Latin American Studies, Library of Congress.

Professor Lechtman was elected Fellow of the American Academy of Arts and Sciences. As director of the research project, "Style in Art and Technology," she was awarded the second-largest grant ever made by the J. Paul Getty Trust Grant Program.

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, 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 the Athena Language Learning Project has acquired national recognition. However, severe controversies within the School regarding the role and mission of FLL at MIT have culminated in the resignation of Professor Claire Kramsch as Section Head and in plans to restructure the Section.

This year has seen the publication of five books by junior faculty and permanent staff, four in literary studies, one in language teaching. Assistant Professor Joseph Brami's reflections on the French writer J e Bousquet, Les troubles de l'invention;  tude sur le doute po tique de J e Bousquet (Summa Publications), explores the difficulties of literary creation. Associate Professor Kathy Crecelius' psychoanalytic treatment of George Sand's early novels, Family Romances: George Sand's Early Novels (Indiana University Press), is a landmark in Sand studies. Lecturer David Dollenmayer's study of the German author Alfred D blin, The Berlin Novels of Alfred D blin: "Wadzek's Battle with the Steam Turbine," "Berlin Alexanderplatz," "Men Without Mercy," & "November 1918: A German Revolution" (University of California Press), is the first comprehensive book on that difficult author. Lecturer Gilberte Furstenberg's French intermediate textbook, En Direct (Harper & Row), offers a wealth of ideas for using authentic texts in the language classroom. Assistant Professor Edith Waldstein's monograph on the German Romantic author Bettine von Arnim, Bettine von Arnim & the Politics of Romantic Conversation (Camden House), sheds light on a little known woman writer of the early 19th-century. Other members of the faculty are pursuing ongoing research in various areas: Linguistics, Second and Foreign Language Acquisition (Professors Catherine Chvany, James Harris, Claire Kramsch, Associate Professor Suzanne Flynn, and Assistant Professor Michio Tsutsui); Foreign Literary Studies (Associate Professors Isabelle de Courtivron, Elizabeth Garrels, and Margery Resnick); Film and Media Studies (Associate Professors Michael Geisler and Edward B. Turk). These publications and scholarly endeavors testify to the intellectual vitality of the Section and to its broad range of interests in various foreign languages and literatures.

The Section has been professionally active as well. In addition to many speaking engagements and participation in conferences and seminars, several events have been organized or hosted by FLL this year: a film series, a drama workshop, and assorted guest lecturers.

Due to the success of its three-year experimental program, Japanese will officially be a part of FLL curricular offerings next year as a two-year language sequence with an experimental third year of language instruction. A course in Technical Japanese is being given as a special program of the 1988 MIT Summer School.

During IAP, FLL offered intensive language courses in three languages: German, Russian, and Spanish. Next year it will include Japanese. Pre-registration for these courses continue to far exceed FLL's budget capacity.

The total enrollment (fifth week figures: 2024) as well as the number of concentrators (total: 193) and majors (total: 15) has remained constant. French still has the largest enrollment (466), followed by German (343), Spanish (319), English as a Second Language (296), Russian (227), World Literature in Translation (221), and Japanese (152). Thanks to the excellent quality of the teaching given both by faculty and lecturers, FLL subjects have received some of the highest ratings in the Student Course Evaluation Guide. Assistant Professor Tsutsui and Lecturer Elena Semeka each received a grant from the Consortium to attend proficiency testing training workshops at the University of Pennsylvania and have integrated their insights into the language curriculum.

Personnel changes this year include the departure of Assistant Professor Brami to the University of Maryland and of Lecturer Dollenmayer to Worcester Polytechnical Institute. Administrative Officer Karen Bushold left in December, and Nancy Lee joined the Section as Administrative Assistant, pending a search for a new Administrative Officer. Richard Larraga joined us in August as Administrative Secretary and Cindy Woolley joined in September as Senior Office Assistant. We congratulate Suzanne Flynn on her promotion to the rank of Associate Professor with tenure. Dr. Tsutsui has been appointed Assistant Professor of Japanese at MIT.

In February 1988, a special committee was appointed by the Dean of the School of Humanities and Social Science to examine in detail the mission and structure of the FLL Section at MIT. It was comprised of Professors Richard Cartwright (Chair), Kenneth Hale, James Harris, Alvin Kibel, Claire Kramsch, Kenneth Manning, Edward B. Turk and Murray Sachs (Brandeis University). The committee report, submitted to the Dean on May 27, will serve as a basis for the future direction taken by the Section.

History Section

This has been an unusually bountiful year for the members of the History Faculty. The honors won by its members began with the award of the American Historical Association's George Louis Beer Prize in European International History to Associate Professor Philip S. Khoury for his book Syria and the French Mandate: The Politics of Arab Nationalism, 1920-1945, which was published by Princeton University Press in 1986. Also in the fall term Associate Professor Peter Perdue was appointed Metcalfe Professor of Liberal Arts and Engineering for 1987-88, and in the spring he was named to the Ford Career Development Professorship in International Studies for 1988-91. Meanwhile, Assistant Professor Sarah Deutsch was made the Cecil and Ida B. Green Career Development Professor for 1987-90. Professor Deutsch also won an NEH fellowship for a year of study at the National Humanities Center at Research Triangle Park, North Carolina. In the course of the year Professor Pauline Maier won both an NEH Fellowship for College Teachers and a fellowship from the John Simon Guggenheim Memorial Foundation. This string of successes continued with Professor Perdue's receiving the MIT Edgerton Award, which is given annually to an outstanding member of the Institute's junior faculty.

Professor Perdue won that award just in time: on July 1, 1988 he will become a tenured faculty member. On the same date Assistant Professor Michael McGerr will become an associate professor. Other notable events of the year include the publication in 1987 of Professor Perdue's Exhausting the Earth: State and Peasant in Hunan, 1500-1850, published by the East Asian Studies Center at Harvard University, and of Professor Deutsch's No Separate Refuge: Culture, Class, and Gender on an Anglo-Hispanic Frontier in the American Southwest, 1880-1940, by Oxford University Press.

Perhaps the most time-consuming activity undertaken by the History Faculty as a group during the past year was its search for a new assistant professor of modern European History. The task was delegated to a committee under the leadership of Professor Khoury, who is the History Faculty's Affirmative Action Officer. Some 275 applications were received for the position in European History, and, owing to the outstanding research and teaching strengths of the final candidates, two persons were appointed: Dr. Douglas Forsyth, a Lecturer in history at Princeton, who works on Italian and comparative European History and holds his Ph.D from Princeton, and Ms. Robin Kilson, a specialist in British history with a strong interest in African History, who is completing a dissertation at Harvard. With the recent resignation of Professor Robert I. Rotberg, who became Academic Vice-President for Arts and Sciences at Tufts University in 1987, Ms. Kilson's appointment will enable the History Faculty to maintain its commitment to the teaching of African History.

Members of the History Faculty were deeply involved in developing the new HASS-Distribution curriculum. Professor Maier served as chair of the Historical Studies Subcommittee and was a member of the HASS-D Overview Committee; Professor Perdue served on the Cultures and Societies Subcommittee. Six subjects proposed by members of the History Faculty will be included in the HASS-D offerings for 1988-89, all under the Historical Studies category. With the help of Professor Perdue and History's Committee on the Undergraduate Program, the History Faculty also designed a new minor in History which will be open to undergraduates for the first time in 1988-89; and with the assistance of Dain Waters, who joined the History Faculty's staff in the fall, the History Faculty assumed responsibility for advising its own majors. (That responsibility was previously executed by the Course XXI Undergraduate Office.) Professors Perdue, Mazlish, and Maier also participated in extended discussions with members of the Program in Anthropology and Archaeology and STS that explored the possibility of history's merging with those programs to form a new department. By the end of the year those discussions unfortunately had come to nought, despite the historians' enthusiasm at the prospect of departmental status. On the other hand, the History Faculty has been actively involved with the Programs in Science, Technology, and Society and Anthropology/Archaeology in developing the new graduate program in the History and Social Study of Science and Technology, the first Ph.D program in the Humanities at MIT.

Historians also served on a wide variety of Institute committees, and played a special role in organizing a series of faculty seminars: Professor Deutsch remained the major force behind the

American Area Studies Colloquium, which drew interested faculty members from across the Institute to monthly meetings; Professor Khoury, with the assistance of Assistant Professor Hasan Kayali, continued to organize the Bustani Seminar in Middle Eastern Studies, which is sponsored by the Center for International Studies, and Professor Bruce Mazlish helped organize a seminar jointly held by History, Literature and the Writing Program.

Staffing needs for the 1988-89 year will be complicated by the absence of Professors Deutsch and Maier throughout the year, of Professor McGerr in the fall (he holds an NEH fellowship that runs through calendar 1988), and Professor Merritt Roe Smith, who holds a joint appointment in STS and History, in the spring. All four of these faculty members are American historians. Fortunately, the History Faculty was able to appoint two excellent Americanists to visiting positions: June Namias, a specialist in Early American History who is completing her dissertation at Brandeis, and Ellen Fitzpatrick, a specialist in 19th and 20th century American History and American Women's History who has taught at both MIT and Wellesley in past years. Professor Kayali will remain with the History Faculty on a half-time appointment during AY 1988-89. He will offer subjects in Middle Eastern History that would normally be taught by Professor Khoury, who is teaching only half time while serving as Associate Dean of the School of Humanities and Social Science.

Professor Maier will end nine years of service as head of the History Faculty on June 30. Her position will be filled in AY 1988-89 by Professor Richard M. Douglas.

Pauline Maier

Literature Section

The Literature Faculty of the Department of Humanities currently has more than 25 majors (in one or another of the Humanities major options), the largest in Humanities and a number that would do credit to small department of English or Comparative Literature at a liberal arts college. Literature also ranks high in the number of students to have completed a HASS concentration. At the same time, the faculty numbers only 15 positions, with some of these drawn away each year by the needs of scholarly research, which (as is often the case in undergraduate programs of literature) often conflict instead of complying with teaching obligations. Unsurprisingly, therefore, the major problem vexing the Literature Faculty continues to be understaffing, with upwards of one-fifth its subjects taught by ad hoc faculty members whose services have been temporarily engaged for this purpose.

The problem is of long standing and is not to be solved in a hurry. Two recent developments, both part of an effort by Dean Ann Friedlaender to bring the various sections of the humanities into line with other departments in the Institute, may point the direction to part of a solution. The reform in the distribution system may effectively work to shift some of the burden of distribution teaching more equitably to other sections and departments in the school, so that a larger proportion of the teaching by the Literature Faculty may be devoted to its own curriculum; and the humanistic disciplines have been encouraged to think about the possibilities of modest beginnings in graduate programs. It is, of course, too early to say what the effects of the curricular reform will be, from the standpoint of student enrollments; and it would be premature to foresee a graduate literature program, even on a modest scale, in the immediate future. But the direction of these efforts is propitious, insofar as they might tend to shift the balance of curricular planning to areas consonant with advanced scholarship and thereby make less imperative the need for faculty to divide their time between scholarship and pedagogy.

As for this year's accomplishments: the Literature Faculty maintained a high level of visibility in the professional world by a variety of publications, by a number of invited talks at universities and papers delivered at professional conferences, by fulfilling an array of duties in contributing editorial services to professional journals and publishing houses, and by the receipt of professional honors, such as grant and competitive appointments at centers and institutions of higher learning.

Two books by faculty members are currently in press: Associate Professor Peter Donaldson's exhaustive work on Machiavelli and the Mystery of State (Cambridge University Press) and Associate Professor David Halperin's The Metaphysics of Desire, a study of Platonism (Yale University Press). Contracts have also been extended to Professor Donaldson for a work on the adaptation of Shakespeare to film (Allen & Unwin) and to Professor Halperin for a collection of essays on the ancient conception of love (Routledge). Further, Professor David Thorburn is active as the general editor of a series of volumes on popular culture and the media, published by Allen & Unwin, and Professor Cynthia Wolff has been contracted by Knopf for a socio-literary study of the subculture of immigrant Irish women in Boston, tentatively title Daughters of the Swan; she is also editing the second volume of the works of Edith Wharton to be published by the Library of Congress. Finally, we should note that Professor A.R. Gurney (as usual) had a new play produced in New York City this year, entitled Another Antigone.

Articles were accepted by or appeared in the following professional journals: Boston Review, Cinema Journal, Critical Studies in Mass Communication, Edith Wharton Chronicle, The Massachusetts Review, Nineteenth-Century Fiction, Partisan Review, and Shakespeare Quarterly. In addition, essays written by members of the faculty appeared in several scholarly collections edited by other hands; these were either commissioned especially for this publication or were reprinted from other sources. The list of publishers includes the University of California Press, Chelsea House, Duke University Press, Johns Hopkins University Press, the University of Michigan Press, Modern Language Association, New American Library, Oxford University Press, and Scribner's. Further, two faculty members contributed a total of three prefaces to scholarly editions of classical or established texts; and two faculty members have published sixteen poems in a variety of journals, among them The Nation, Prairie Schooner, Texas Review, and (somewhat more prestigiously) The Yearbook of American Poetry.

Invited papers by faculty members were given at major conferences called by learned societies and by colleges or universities. Several members of the Literature Faculty were also active in editorial or consultational capacities for various funding organizations, journal and university presses.

We are pleased to record the award of the Andrew W. Mellon Fellowship at the Stanford University Humanities Center to Professor Halperin, the appointment of Associate Professor Stephen Tapscott as Poet-in-Residence at the Karoly Institute in Vence (France) and the award of a National Endowment for the Humanities Fellowship to Assistant Professor Rita Goldberg. We also record the award of promotions at the rank of Professor to Professor Donaldson and at the rank of Associate Professor (without tenure) to Theoharis C. Theoharis.

We conclude by reporting the Literature Faculty's continuing involvement with a modest but remarkable experiment at MIT. As part of their effort to draw faculty from different schools at the Institute in closer contact with one another, Deans Friedlaender and Margaret MacVicar have sponsored a series of time-intensive miniseminars offered by departments to faculty largely, but not exclusively, from other schools. For the last two of the three years that this experiment has been in progress, the Literature Faculty has offered a week's intensive study and discussion of some manageable area of literary studies. The degrees of interest generated by the entire program (not just the literary end of it) has been, I think, surprising even to the participants; most importantly, the program in general appears to be decisively successful in its overriding aim. Faculty outside the Institute, hearing of the program, have envied it; those within who have experienced it derive an enhanced sense of the Institute's possibilities for intellectual collegiality and are eager for more. For those offering the seminars, the challenge posed by having to present a professional viewpoint to a highly educated lay audience is no less rewarding, for it requires one to rid one's professional discourse of easy reliance on jargon and professional cant, while maintaining its professional quality. We hope that ways will be found not only to sustain this program, but even to enhance it.

ALVIN C. KIBEL

Music and Theater Arts Section

Following an initiative proposed by the Committee to Review the Arts at MIT and pursued by Dean Ann F. Friedlaender and Professor Marcus Thompson (in his dual role of 1986-87 Chair of the Music Section and Coordinator of Theatre Arts) the Music Section this year became Music and Theater Arts. Our mission is to build as strong a structure for theatre and dance as music now enjoys. We in music were pleased to welcome our colleagues, whose artistic and practical problems we share. Our first task as an enlarged section was to conduct a search for a Director of Theater Arts, which we are in the process of concluding.

In the last few years our music program has achieved one of its primary long-range goals. More of our gifted student performers are enrolling in our subjects than ever before, and the integration of performance and study of musical texts, long our intent, has become a reality. In contrast to music programs in many liberal arts colleges, our curriculum has been built around the making of music. One of our most popular courses, enrolling 80 students each term, is 21.641 Harmony and Counterpoint I, the only practical arts course presently available to MIT undergraduates as a HASS distribution course. A total of 1180 students enrolled in credit-bearing subjects, with an additional 300 students participating in co-curricular performance activities directed by the Section.

The Section continues to be governed by a yearly rotation among five of the faculty, a system which has produced greater participation in the planning of our program, while allowing the continuation of important careers in the professional music world. Professor David Epstein, composer, theorist, and conductor of the MIT Symphony, takes the Chair for 1988-89.

Space problems have continued to be a major concern, heightened by the extreme lack of facilities for our new colleagues in Theater Arts. A committee on facilities, involving Dean Friedlaender, Professor Thompson, Professor John Harbison and Administrative Officer Nancy Cavanagh has been laying the foundations, in meetings with Institute administrators, for important improvements in our facilities. We have been able to communicate our conviction that the performing arts belong together at MIT, both in place and in spirit.

In this connection the December opening of Killian Hall, formerly the site of the Hayden Gallery, was a happy event. Killian Hall gives us a small, attractive venue for chamber music over which we have some substantial control. Among the initial events there were concerts in our Composers in Recital series, co-sponsored by the MIT Arts Council and the National Endowment for the Arts. This new series presented eight American composers in solo recitals preceded by a lecture. Composers featured were Professor Harbison, on piano; William Albright, organ and harpsichord; Anthony Davis, piano; Joan La Barbara, voice; Richard Trythall, piano; Les Thimmig, reeds; Frederic Rzewski, piano; and Anthony Braxton, reeds. The lectures preceding the recital programs were particularly interesting and provided great insight into the composers' worlds. The series attracted wide attention and is being prepared for national radio distribution by WGBH.

Concerts sponsored by the Section continue to flourish. Programs in our Chapel Series featured a variety of soloists and ensembles, both from the Boston area and on occasion a visiting artist from abroad, performing music from the Renaissance to works written by contemporary composers. The Series continues to provoke expressions of appreciation, interest and enthusiasm from a core of regular subscribers.

The Guest Artist series brought to Boston the Smithson, Lark, and Ridge Quartets and were attended by large audiences from the Institute and the community. The MIT organizations again had healthy and productive seasons. The MIT Symphony Orchestra was conducted in the fall by Professor Epstein, in the spring by Visiting Conductor Alan Yamamoto, and its performance of Brahms Fourth Symphony was a highlight of the Killian Memorial ceremony in May. The Choral Society, under Senior Lecturer John Oliver, concluded its season with a distinguished performance of Bach's B Minor Mass. The MIT Chamber Players were able to incorporate the talents of a number of exceptional undergraduate performers, notably pianists Jee-Lian Yap and Jee-Hoon Yap and bassoonists Erica Anderson and Cynthia Harris.

Theater Arts had an equally productive year with performances by the Shakespeare Ensemble of Hamlet, directed by Kristin Linklater, and The Merchant of Venice, directed by Kevin Coleman. During IAP the Shakespeare Ensemble sponsored a five-day intensive workshop on Speech Production and Projection which was given by Ms. Linklater, who is an internationally known expert in the field. The workshop was open to the MIT community and well attended.

Dramashop productions included an evening of four of Samuel Beckett's one-act plays and Tom Stoppard's The Real Thing, both directed by Bob Scanlon, and Christopher Durang's The Marriage of Bette and Boo, guest directed by Scott Ziegler.

Each spring the Dramashop has an evening of student-written one-act plays. This year 16 scripts were submitted which were all producible, an unprecedented phenomenon. Four plays were performed.

A number of graduating seniors produced unusually fine work. Julio Friedmann was given the Wiesner Award for his achievements as both composer and actor. His composition recital in May was one of the highlights of the year. Alice Lin, concertmaster of the Orchestra, received the Sudler Prize for her contribution to the arts at MIT, and Eric Ostling was awarded the Edgerton Award for his work as a composer and performer. Ostling's String Quartet was presented as a reading by members of the Muir Quartet at a year end celebration of the work of our outstanding students.

Faculty and staff continued to be professionally active and inventive in applying their professional interests to the needs of the Institute. Associate Professor Jeanne Bamberger was awarded a Guggenheim Fellowship to pursue her work in music and cognition, a by-product of which has been the development of new interdisciplinary courses for the MIT curriculum. Professor Epstein concluded work on his new music-theoretical exploration of concepts of musical time, substantially supported by the Humboldt Foundation in Munich.

Professor Stephen Erdely's research in the field of Hungarian folk music resulted in the publication of his articles "Complimentary Aspects of Bartok and Kodaly's Folk Song Researches" in Bartok and Kodaly Revisited, Academie of Science, Budapest and "Folk Music Research in Hungary until 1950" in Current Musicology. Professor Erdely also began preparation for the hosting of the international conference in Ethnomusicology at MIT in 1989. Professor Harbison accepted commissions from the Baltimore Symphony, the Santa Fe Chamber Festival, Lincoln Center, and the Library of Congress. Associate Professor Lowell Lindgren has completed three extensive studies concerning opera in London at the time of Handel and read papers at several international conferences abroad. Professor Thompson concertized in Europe, Russia, and throughout the United States. Professor Barry Vercoe again presided over an innovative series of concerts of music involving electronic media at the Wiesner Building. Assistant Professor Peter Child finished work on a large work for chorus, soloists and orchestra, commissioned by the Cantata Singers.

Senior Lecturer Edward Cohen completed work on a full length opera based on a story by Tergenev. Senior Lecturer Oliver repeated his success with Martino's White Island, in which he conducted the Tanglewood Festival Chorus and the Boston Symphony in both performance and recording. Senior Lecturer Beth Soll presented her own company, together with the African music group Malumbo, in Kresge Auditorium as part of Dance Umbrella's Spring Festival.

We received with regret the resignation of our long-time colleague, Professor John Buttrick, who has moved to Switzerland to perform and to teach. As the first stage in replacing his versatile talents, we conducted a search for a Lecturer in piano performance and introductory teaching, resulting in the hiring of David Deveau, former Director of the New School of Music in Cambridge and member of the Boston Chamber Music Society.

We were joined by Maggie Devine as administrative assistant, who along with Laura Palladino and Mary-Lynne DiCenso have provided the Chair, Administrative Officer Cavanagh, and Concert Coordinator Clarise Snyder with imaginative and skillful support in taking on the enlarged staff and complicated diplomacy involved in becoming Music and Theater Arts.

JOHN HARBISON

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 undergraduate and graduate students, within the various engineering departments, continue to hold their enrollments and are expanding to new 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 Associate Professor James Paradis and Lecturer Edward Barrett as co-directors, was a big success in its first 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. Professor Elzbieta Ettinger (Chodakowska) spoke on "The Biographer as Sleuth", revealing the struggle she encountered researching and writing her work Rosa Luxemburg: A Life. In lecture "Beyond the Skill vs. Content Debate: the Multiple Discourse Worlds of the Foreign Language Curriculum," Professor Claire J. Kramsch shared her insight into the role of language learning. The MIT and larger communities responded enthusiastically to the events.

Two faculty members released new books this year. Lecturer Barrett published Text, ConText, and HyperText: Writing with and for the Computer with MIT Press. Associate Professor Harriet Ritvo published The Animal Estate: The English and Other Creatures in the Victorian Age, which has received world acclaim.

Dr. Thomas Simmons will join the Program as Assistant Professor of Writing, and Dr. Alan Lightman will join as Professor of Science and Writing.

KENNETH R. MANNING

Department of Linguistics and Philosophy

The Department has spent considerable time and energy this year on matters related to curricular change. Alterations in the General Institute Requirements in the Humanities, Arts, and Social Sciences necessitated a review of the Department's offerings in that category. The review was probably overdue; at any rate, it resulted in some eliminations, some valuable rethinking of subject matter, and the institution of a new subject, 24.04J Justice, to be taught by Associate Professor Joshua Cohen. Another new subject, 24.250 Topics in Philosophy, will be required of majors in philosophy; and it will also form part of the newly introduced minor in philosophy. Designed as a seminar, the subject will provide undergraduates an opportunity for intensive study of a single book, or collection of closely related articles. With respect to graduate education, much thought was given to the curricular details of a proposed extension to five years of the present four-year PhD program in linguistics.

Research: Linguistics

Research in linguistics continued this year at its usual heady pace. Topics of major interest included the following: the explication of "least effort" principles that have been suggested in explanation of a variety of syntactic phenomena and their relationship to other properties of language design that minimize redundancy; strict cyclicity and other conventions on the application of phonological rules; the reanalysis of rightward movement in Universal Grammar; continued development of the theory of lexical knowledge, involving work on Haitian, Miskitu, Nicaraguan English, Uru, Winnebago, and Warlpiri.

Research: Philosophy

Research this year engaged topics from a wide variety of fields within philosophy. Worthy of special mention are: provability logic; the consistency of Fregean arithmetic; the redundancy theory of truth; philosophical issues in phonology and semantics; the relationship of lexical change to scientific development; topics in the philosophy of mind -- in particular, mental causation and so-called narrow content; moral realism; deliberation and democratic theory; rights, and their relations to risks, liabilities, and responsibilities; Hegelian social theory; topics in the history of 17th century philosophy, with special attention to the philosophy of Descartes.

Publications

Philosophical Essays by Professor Richard Cartwright was published by the MIT Press. A companion volume, On Being and Saying, Essays for Richard Cartwright, edited by Professor Judith Jarvis Thomson, was also published by the Press. The book includes essays by colleagues, students and a former teacher of Professor Cartwright. Two linguistics books by Institute Professor Noam Chomsky were published during the year: Language and Problems of Knowledge: The Managua Lectures (MIT Press) and The Chomsky Reader, edited by J. Peck (Pantheon Books). The publication this year of the final volume of Professor Irving Singer's trilogy The Nature of Love, entitled The Modern World (The University of Chicago Press) has sparked much interest from local, national and international news media.

Honors and Awards

Professor Chomsky was one of three recipients of the prestigious Kyoto Prize in Basic Sciences given by the Inamori Foundation, Kyoto Japan. Professor Chomsky will attend the award ceremony in November. We are pleased to report that Institute Professor Morris Halle has been elected to the National Academy of Sciences. Laurance S. Rockefeller Professor Thomas S. Kuhn received an honorary degree from Denison University and is president-elect of the Philosophy of Science Association. Professor James Higginbotham was Visiting Fellow at Wolfson College, Oxford University, for the latter part of that university's Trinity Term.

Leaves of Absence

While on sabbatical leave, Professor Sylvain Bromberger was Visiting Scholar at the Center for the Study of Language Information at Stanford University. Professor Thomson continued research on the concept of rights, supported by a grant from the National Endowment for the Humanities.

Personnel

Professors Richard Kayne and Luigi Rizzi will be leaving the linguistics faculty. Professor Kayne has accepted an appointment at CUNY, and Professor Rizzi will continue his association with the linguistics department at the University of Geneva, Switzerland. We wish them both well.

We are pleased to announce that Assistant Professor Richard Larson has been promoted to Associate Professor and Assistant Professor Donca Steriade to Associate Professor with tenure.

As we mentioned last year, Professor Robert Stalnaker, noted philosopher of mind and language, will join the philosophy faculty in the fall. We are also pleased to report that Associate Professor David Pesetsky, currently at the University of Massachusetts (Amherst), will join the linguistics faculty in the fall. Professor Pesetsky specializes in syntactic theory.

RICHARD L. CARTWRIGHT

Department of Political Science

Issues concerning planning and faculty recruitment have dominated the agenda of the Department of Political Science this year. Although several searches were conducted, we did not find candidates of outstanding quality whose interests were sufficiently close to our needs. Thus no new appointments were made, breaking a string of three years in which two new faculty members each year were brought into the department. Our recruitment efforts until now have been keyed essentially to specific vacancies created by the departure of junior or senior faculty members. It has become increasingly clear that we need to take a longer view of faculty development, shaping a strategy that will guide us through a transition period of four or five years.

In our faculty deliberations, two important general conclusions have emerged thus far. First, we need to make several senior appointments of a quality that will demonstrate convincingly our intention of remaining among the top half-dozen political science departments in the country. This represents a clear modification of a search strategy that has in the past consistently favored the appointment of well-qualified junior people, the best of whom in time join the tenured ranks. The quality of our recently tenured faculty demonstrates that this strategy has served us well, but the current need for two or three senior appointments from outside is clear. Second, we need the flexibility to develop a multi-year recruitment strategy, and our planning is thus proceeding on the assumption that we will be making seven or eight appointments over the next four or five years.

On the educational front, this has been a year of refinements and improvements in both graduate and undergraduate programs. Despite our perennial shortage of financial aid resources, we continue to attract a fair share of the most outstanding graduate students in the country. A revised financial aid system, introduced last year, seems to be spreading our resources more equitably among a somewhat larger fraction of the graduate student body, and our aid packages now regularly include obligations to work as a research or teaching assistant during the second or third year of the program. Most students regard these assignments as appropriate and desirable aspects of their professional training. We were pleased this spring to learn that one of our recent graduates, David Friedman, had won the American Political Science Association's Award for the best dissertation in comparative politics, in his case on politics and economic development in Japan; this was the second win in a row for us, Fran Hagopian having received the same award last year for her work on Brazil.

Morale has been high in the undergraduate program, partly because of a somewhat larger number of majors than usual. There are indications that the Institute's efforts to increase the diversity of its student body may have attracted more undergraduates interested in political science as a sole or double major. Professor Michael Lipsky, and the undergraduate program committee which he chairs, have sponsored some curricular changes designed to improve the quality of the undergraduate thesis experience and to introduce some research-oriented core subjects into the curriculum. Along with other parts of the School, we have taken advantage of the opportunity to develop a minor program, which will be available to undergraduates next year.

The faculty continues to produce a steady stream of books, chapters, articles, and monographs, not to mention reasoned or impassioned op ed pieces, letters to the editor, and memos to colleagues. Space being at a premium, we can mention only the books published or accepted for publication during the year. Associate Professor Russell Neuman's new book on The Future of the Mass Audience is in the process of publication by Harvard University Press. Professor Lucian Pye has written a provocative set of essays on Chinese political culture to be published by the University of Michigan Press under the title The Mandarin and the Cadre: Political Cultures of China. The Cambridge University Press will soon be issuing Assistant Professor Charles Stewart's study of Budget Reform Politics: The Design of the Appropriations Process in the House, 1865 to 1921. Associate Professor Richard J. Samuels' monograph on The Business of the Japanese State: Energy Markets in Comparative and Historical Perspective appeared this year under the imprint of the Cornell University Press. It should be noted, too, that his earlier book on The Politics of Regional Policy in Japan has won the Ohira Memorial Prize for 1987, an award honoring the most outstanding work of the year on the Asia-Pacific region. Finally, Assistant Professor Richard Valelly's study of Radicalism in the States: The Minnesota Farmer-Labor Party and the Political Economy will be published next year by the University of Chicago Press.

The most notable departmental event of the year was the MIT Symposium on World Telecommunications Policy organized in January in tribute to Ithiel de Sola Pool. Over two hundred people from many countries attended the two-day symposium organized by Professor Harvey Sapolsky with the intellectual, financial, and logistical support of several former graduate students from our communications program now occupying positions in the telecommunications industry and governmental regulatory agencies. An edited version of the symposium transcript has just appeared, and will be followed in due course by a book of essays on

communications and regulatory policy. The occasion was a worthy tribute to Ithiel Pool, an extraordinarily creative social scientist whose research on communications won international recognition for its methodological innovativeness, theoretical sophistication, and concern with domestic and international policy issues.

Faculty members were engaged in their usual variety of outside professional activities and received their full share of awards and honors during the year. Professor Hayward Alker was named the first recipient of the Olof Palme Professorship, established by the Swedish government in memory of the late Prime Minister and administered by the Swedish Council for Research in the Humanities and Social Sciences. Professor Alker will teach next spring in Uppsala and Stockholm. Professor Suzanne Berger directed for the second year her innovative educational activity entitled Seminar XXI, Foreign Politics and the National Interest, which brings together once a month a rotating group of distinguished scholars to interact with about forty Fellows selected from the military services, executive branch departments, and private companies. Professor Berger has, in addition, served on a number of important social scientific bodies, including the Social Science Research Council's Board of Directors and the Committee on Studies of the Council on Foreign Relations. Professor Lincoln P. Bloomfield devoted some of his time this year to refining and expanding a computer program called CASCON (Computer-Aided System for Analysis of Local Conflicts) and demonstrating its potential to audiences in Washington, Geneva, and United Nations headquarters in New York. First developed in the late 1960s for use in simulated political games involving local conflicts, CASCON has been utilized in political games and in research, in both government agencies and academic research centers. Professor William E. Griffith was awarded this spring the Commander's Cross of the Order of Merit, one of the highest awards of the Federal Republic of Germany. Professor Griffith recently served as Minister-Counselor for Cultural Affairs at the American Embassy in Bonn, culminating a more than forty-year professional and personal association with the Federal Republic. Professor Samuels continued to expand the scope of the MIT-Japan Science and Technology Program, now the largest and most effective American effort to help educate scientists and engineers about Japan; he also became a member of the Joint Committee on Japanese Studies of the Social Science Research Council. Professor Myron Weiner completed a highly successful first year as Director of the Center for International Studies, stimulating the creation of seminars, workshops, and research projects in substantive areas in which the Center has not worked in recent years.

The Department has suffered a blow this spring with the retirement of Senior Lecturer Louis Menand III, who has taught American Politics with unparalleled success to undergraduates since coming to MIT in 1968. Dr. Menand is legendary among undergraduates both for his ability to create an exciting and demanding classroom environment and for his warm and welcoming interactions with students in other settings. It was absolutely fitting that this spring he should have received the student-selected Everett Moore Baker Memorial Award for Excellence in Undergraduate Teaching. In his other capacity, as Special Assistant to the Provost in three administrations, Dr. Menand served the Institute in many ways, most notably by his active engagement with civil liberties questions and other controversial social and political issues. We are pleased that he has agreed to return next year to teach his favorite subject, the Supreme Court, but his full-time presence will be sorely missed.

Finally, I am pleased to report that Professor Berger has agreed to accept nomination, by acclamation of her colleagues and of the Administration, as next Head of the Department. I believe there could be no better choice. After a semester's research leave, Professor Berger will take over in January. As for the departing Head, after fifteen years of nearly full-time administrative service of various sorts, he is looking forward eagerly to the responsibilities and pleasures of the professorial life.

DONALD L.M. BLACKMER

Program in Science, Technology, and Society

The new graduate program in the History and Social Study of Science and Technology, new initiatives in science and technology policy studies, and the undergraduate curriculum were the focus of many of the activities of the Program in Science, Technology, and Society (STS) in the last year.

The graduate program, which will start next fall, received an outstanding group of applicants after approval by the MIT faculty in October. Four of the program's top five applicants accepted admission, despite our limited capacity to offer financial support. Three of the four basic proseminars will be offered next year; in addition, Professor Leo Marx will offer a new seminar on Interpretations of American Culture, and Associate Professor Richard Lester (Nuclear Engineering and STS) will offer a new seminar on Technology, Productivity, and Industrial Organization. The graduate program Steering Committee consists of Professors Merritt Roe Smith (Director of Graduate Studies, STS), James Howe (Associate Professor and Head, Anthropology/Archaeology), Peter Perdue (Associate Professor of History), and Kenneth Keniston (Professor and Director, STS). The new program will complement current STS graduate work with students in Political Science.

Strengthening its work in science and technology policy studies is one of the Program's long term goals. During the past year, an informal committee co-chaired by Professor Daniel Roos (Director, Center for Technology, Policy and Industrial Development, School of Engineering), and Professor Keniston, including faculty from Departments of Urban Studies, Political Science, Nuclear Engineering, met regularly to consider how MIT's efforts in this area could be focussed and augmented. Discussions will continue in AY 1988-89 on how best to coordinate and improve MIT's already important work in science and technology and policy studies. The STS Program welcomes the opportunity to expand its work in this important area and, in the process, to strengthen its links with other Schools.

The Program's undergraduate curriculum was extensively revised. Several low-enrollment subjects were dropped; new faculty effort was concentrated on Context or HASS-D subjects. An STS Minor was developed, and Bulletin listings were completely reorganized. Three new HASS-D's and three new Context Courses will be offered next year.

The Program made two new appointments this year, with a third pending. Deborah Fitzgerald of Harvard University was appointed Assistant Professor of the History of Technology; Lisa Rofel of the University of California (Berkeley) was appointed Assistant Professor, joint with Anthropology/Archaeology. A third appointment in technology and national security studies, made in collaboration with Defense and Arms Control Studies, is pending. Also joining the STS faculty part-time next year are Professor Jill Conway, appointed a Visiting Lecturer in the Women's History, and Professor Lester of the Department of Nuclear Engineering. Professor Conway is a distinguished historian and former President of Smith College. Professor Lester is the Staff Director of the MIT Commission on Productivity. Next year, the Program will initiate a search for a junior faculty member in the history of science.

The Program sponsored, cosponsored, or hosted a number of special activities during the last year. Professor Carl Kaysen ably organized the STS Monday luncheon discussions, which provide a broad overview of science and technology studies. Professor Marx organized a regular Faculty-Graduate Student Workshop for the first time this year. The Political Science-STS graduate students ran a bi-weekly Seminar Series, with research presentations by students and faculty. The Program hosted or co-sponsored many other events. Among them were Dr. John Gibbons (with the Center for Technology, Policy and Industrial Development), a Symposium on the Visual Arts and the World of High Technology (organized by Professor Marx, cosponsored with the List Visual Arts Center), the Dibner Memorial Convocation (with Dibner Institute for the History of Science and Technology), the Europe and Technology Seminars (with the Center for International Studies and the Center for European Studies [Harvard]); and a number of talks.

STS faculty had an unusually productive year. Associate Professor Louis Bucciarelli published three articles on engineering design, with two more in press. With Professor Donald Schon of Urban Studies and Planning he is the co-principal investigator of a National Science Foundation project on design in architecture and engineering. Professor Kaysen continued his history of the militarization of American foreign policy; he was a member of the American Academy Committee on International Security Studies and a director or trustee of many academic and corporate institutions. Professor Marx's two books, The Pilot and the Passenger and The Railroad in American Art (edited with Susan Danly), were published this year. He was Chair of the American Literature Section, Modern Language Association, and lectured widely throughout the country. Associate Professor Emma Rothschild has three articles published or in press on development and contemporary economics. She is a member of the Royal Commission on Environmental Pollution (Great Britain) and of the Governing Board of the Stockholm International Peace Research Institute, among other activities. Professor Loren Graham published a number of articles on current trends in Soviet science, technology and society. His book, Science, Philosophy and Human Behavior in the Soviet Union, published in 1987, will be followed next year by an edited volume, The Social and Political Implications of Science and Technology in the Soviet Union. He continues to administer a three-year grant funded by the National Endowment for the Humanities (NEH) on the humanistic dimensions of Soviet science and technology. Professor Smith's volume, Science, Technology and the Military (edited with Everett Mendelsohn and Peter Weingart), will be published this year. Active at MIT in STS Committees, School committees, and Institute committees, Professor Smith will become President of the Society for the History of Technology in October. Professor Leon Trilling's article on "Styles of Military Technical Development..." will be published in the volume edited by Professor Smith. In the fall of 1987, Professor Trilling was Visiting Atherton Bean Professor at Carleton College, where he gave the Ian Barbour Lectures. Associate Professor Sherry Turkle published or has in press five articles on computation and the sociology of science. She received a grant from the MacArthur Foundation for a study of computation in the Soviet Union. Professor Charles Weiner, with two other MIT faculty members, initiated a new context course, "Engineers, Scientists, and Public Controversies." He published articles on genetic engineering and oral history, and was a consultant to the Smithsonian Institution, Rensselaer Polytechnic Institute, Keystone Center, the National Science Foundation, and the National Endowment for the Humanities.

The Program continued to provide a home for a number of Visiting Scholars. Present for at least part of the year were Alexander Barzel (Professor of Philosophy, Israel Institute of Technology, Haifa), Jill Conway (see above), Graziela De Oliveira (Adjunct Professor, Department of Economics, Federal University, Paraiba, Brazil), Peter Doeringer (Professor of Economics and Director, Institute for Employment Policy, Boston University), Horst Kern (Professor of Sociology, University of Göttingen, West Germany), Rafael Pardo (Professor of Sociological Theory, University of Madrid, Spain), Wolf Schafer (Professor of Political Science, University of Darmstadt, Germany), Marc Trachtenberg (Associate Professor, Department of History, University of Pennsylvania), Stephen Weininger (Mellon Research Fellow, Professor of Chemistry, Worcester Polytechnic Institute), and Jizhong Zhou (Associate Professor of the History and Philosophy of Science, University of Science and Technology, Beijing).

John Staudenmaier, SJ, Professor of the History of Technology at the University of Detroit, ably replaced Professor Smith during the latter's leave in the spring semester. Professor Rothschild is resigning from the Program after ten years to accept a Senior Research Fellowship at King's College, Cambridge. We will sorely miss her brilliance and the breath of her knowledge in political economy, science policy and arms control studies.

KENNETH KENISTON

The Center for International Studies entered a new phase of activities under the directorship of Professor Myron Weiner, the fourth director since the Center was founded in 1952. While the Center continues to emphasize international issues closely related to science and technology, especially in its major national programs on defense and arms control and on Japanese science and technology, it has begun to expand its activities on the political economy of advanced industrial societies and on political and economic change among developing countries. A one million dollar grant for five years commencing on July 1, 1988 from the MacArthur Foundation for work on international peace and security will serve both to strengthen the Center's work in defense and arms control and enable the Center to expand its activities in the development field.

This past year the Center initiated a series of workshops in comparative and regional studies, which drew the participation of faculty and graduate students throughout the Institute. Under the direction of Professor Judith Tandler (Urban Studies and Planning) a workshop on institutional perspectives on the state and third world development was organized, focusing on the recent experiences of developing countries with government policies intended to alleviate poverty. A seminar was initiated on the future of international migration, funded by a grant from the Sloan Foundation, which explored the factors likely to affect future international population movements, largely among developing countries and from developing countries to advanced industrial societies. The seminar was organized by the Inter-University Committee on International Migration whose MIT members include professors Nazli Choucri (Political Science), Jerome Rothenberg (Economics) and Myron Weiner (Political Science, chair). Under the chair of Associate Dean Philip S. Khoury (Professor of History), the Emile Bustani lectures on contemporary Middle East issues brought leading scholars and government officials to MIT in what has become one of the most widely attended of the Center lecture series. The Center supported the Joint MIT-Harvard Seminar on Political Development, headed by Professors Weiner and Samuel P. Huntington (Center for International Affairs, Harvard University). In 1987-88 the seminar's theme was the "Crises of Development in Marxist-Leninist Regimes." A faculty seminar on South Asia continued under the auspices of the Center and the Boston University Asian Development Center. The Center also served as the MIT anchor for a joint MIT-Harvard faculty and student group on Women and International Development. A grant from the Ford Foundation will enable the Center to organize a series of workshops in 1988-1989 on state directed efforts to restructure the Islamic societies of Iran, Afghanistan and Pakistan.

Two seminars were organized on state-economy relations in advanced industrial societies. A faculty seminar with guest lecturers, was organized by Professor Suzanne Berger (Political Science). A second seminar, a graduate student lunch series, provided graduate students and faculty with an opportunity to discuss student research proposals, research findings and thesis chapters.

Defense and Arms Control Studies continued to be major components of the Center's work during the past year. Research carried out by faculty in the Program dealt with such topics as: US-Soviet defense policy (Professor Jack Ruina, Electrical Engineering and Computer Science); arms control and disarmament, nuclear weapons proliferation, the nuclear winter phenomenon, and the greenhouse problem (Professor George Rathjans, Political Science); Soviet defense and arms control doctrine and the Soviet style of decision-making on weapons procurement and deployment (Associate Professor Stephen Meyer, Political Science); 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 (Lecturer, Dr. Steve Miller, Political Science). Research Associate, Dr. William Durch, worked on strategic defense and arms control and European arms control issues.

Others contributing to the Defense and Arms Control Studies Program were a number of visiting scholars--Professor Bernard Gonsior (the Institute for Experimental Physics of Ruhr University in West Germany), Professor Bernard Goulard (the Laboratory of Nuclear Physics at the University of Montreal), Professor John Holdren (the Energy and Resources Group of the University of California at Berkeley, and recipient of a MacArthur

Fellowship), Dr. Michael May (the Lawrence Livermore National Laboratory of the University of California), Professor Barry O'Neill (the Department of Industrial and Engineering and Management Sciences at Northwestern University, and a recipient of a MacArthur Fellowship), and Dr. Herbert York (the Institute of Global Conflict and Cooperation at the University of California at San Diego).

William Durch and Eugene Rumer, received their Ph.D.'s in the 1987-88 academic year. To date 38 men and women have received their Ph.D.'s in political science with a specialization in Defense and Arms Control Studies.

The Program also conducted the sixth MIT-Harvard Summer Program on Nuclear Weapons and Arms Control in June, 1987 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.

The Center's work on defense and arms control is supported by the Carnegie Corporation, the Ford Foundation, the Hewlett Foundation, the Sloan Foundation, the US Department of Defense and, starting in July, 1988, the MacArthur Foundation. This year the Carnegie Corporation renewed its support to the Program with a \$1.1 million grant. Support is also provided by MIT through its Fund for International Security and Arms Control.

The MIT-Japan Science and Technology Program continues to foster closer relations between scientists, engineers and industrial managers in the United States and in Japan. Japanese language instruction has been expanded at MIT (more than 100 students are currently enrolled) and 18 interns were sent to Japan this year. In the summer of 1988 the Program initiated an eight week workshop for computer scientists and electrical engineers focusing on the learning of technical Japanese. Professor David Mills, Department of East Asian languages of the University of Pittsburgh, was at the Center in 1987-88 organizing the workshop and preparing materials.

The Japan Program hosted a meeting of Japanese and American professionals from government, industry and academia to examine the Japanese technology process. A Study Group on security, technology and East-West trade, consisting of business representatives and government observers from both the United States and Japan, has been initiated to examine differences between the two countries on these critical issues. It is directed by Michael W. Chinworth, Program Associate. The Program also ran a number of activities within MIT-- a weekly Japanese lunch table, a Japanese reading room, a modern Japanese movie series, a monthly seminar on Japanese science and technology, and a year long orientation seminar to prepare interns going to Japan.

The Program is directed by Associate Professor Richard Samuels (Political Science) and Associate Professor D. Eleanor Westney (Management), with support from the Japan Foundation, the US-Japan Friendship Society, the Cornelius Vander Starr Foundation, the Hitachi Foundation, the National Science Foundation, and eleven corporate sponsors. Professors Samuels and Westney are currently engaged in a study of changes in Japanese R&D facilities, with Professor Samuels focusing on the aerospace industry and Professor Westney on the construction industry.

This year, the Japan Endowment Fund, established in 1980 by a gift from the Japanese Ministry of Foreign Affairs and administered by the Center, awarded grants to four MIT faculty members and researchers for work in the area of international energy and related technology policy.

During the year the International Food and Nutrition Program, under the direction of Institute Professor Nevin Scrimshaw, cosponsored a workshop in Caracas, Venezuela to develop dietary goals and guidelines for health in Latin America. The report will appear as a book in the fall of 1988. With support from the United Nations University, IFNP also served as the coordinating center for two global projects concerned with the development of a computerized system for accessing food composition data from all countries (INFOODS) and the development of a directory of food intake data (INFID) to be used for epidemiological studies of diet and chronic disease.

Under the direction of Professor Berger (Political Science) for the second year the Center ran Seminar XXI: Foreign Politics and the National Interest. 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 foreign 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. This year's faculty included MIT Professors Stephen Meyer, Michael Piore, Richard Samuels, Lucian Pye and Myron Weiner, Professor Robert Legvold (Columbia University), Professor Terry Karl (Stanford University), Professor Richard Millet (University of Southern Illinois), Professor Bernard Lewis (Princeton University), Professor Shaul Bakash (George Mason University), Drs. John Steinbruner, Ed Hewett and Harry Harding (Brookings Institution), Dr. Gary Sick (Ford Foundation), Professors Gail Lapidus and John Zysman (University of California, Berkeley), Professor Adam Ulam and Dr. Walid Khalidi (Harvard University), Hannes Adomeit and Josef Joffe (Federal Republic of Germany), Yehoshafat Harkabi (Israel), Koji Watanabe and Tatsuo Arima (Japan), Ashish Nandy (India), and Marc Perrin de Brichambeau (France).

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 an alumnus of MIT, Harry Kalkar, enabled the program to expand in the number and mix of fellows.

Books published by members of the Center this past year include Professor Lincoln Bloomfield, The Management of Global Disorder, Professor Loren R. Graham, Science, Philosophy and Human Behavior in the Soviet Union (Columbia University Press, 1987), Professor Khoury, Syria and the French Mandate, (Princeton University Press, 1987), Professor Miller, co-editor, Naval Power and National Security (Princeton University Press, 1988), Professor Samuels, The Business of the Japanese State: Energy Markets in Comparative and Historical Perspectives (Cornell University Press, 1987), Professor Lance Taylor, Varieties of Stabilization Experiences (Oxford, Clarendon Press, 1988), Professor Weiner, co-editor, Understanding Political Development (Little, Brown, 1987) and co-editor, Competitive Elections in Developing Countries (Duke University Press, 1987), and Professor Westney, Imitation and Innovation (Harvard University Press).

MYRON WEINER

Center for Materials Research in Archaeology and Ethnology

The 1987-88 academic year was particularly lively at the Center for Materials Research in Archaeology and Ethnology (CMRAE), with the addition of a group of key new faculty and research staff. Dr. Dorothy Hosler, postdoctoral associate at the Center, was invited to join the MIT faculty as assistant professor of archaeology, a joint appointment in CMRAE and the Anthropology/Archaeology Program. She will commence her faculty appointment in September 1989, upon completion of her postdoctoral research. Dr. Ian Whitbread, research fellow at the Department of Archaeology, University of Southampton, England, was appointed principal research scientist in ceramics and archaeology. Dr. Whitbread will begin his residency at the Center in September 1988 when he will establish and direct the CMRAE ceramic research facility. Dr. Leon Shiman joined the Center as research associate in computation to undertake research in interactive graphics at the CMRAE Computation Facility, and Mr. Guy Pollard, scientific instrument maker, assumed the responsibilities of supervisor of the CMRAE Graduate Laboratory.

Dr. Thomas Cummins and Dr. William Dewey, both art historians, began their 18-month tenure as post-doctoral fellows of CMRAE in an exciting research program initiated by Dr. Hosler and Dr. Susan Terry Childs, Center archaeologists. The research of these four scholars, which they are conducting in teams of two (Drs. Hosler and Cummins, Childs and Dewey), is supported by a major three-year, \$469,000 award to CMRAE from the Grant Program of the J. Paul Getty Trust. The grant to CMRAE is the second largest research award made to date by the Trust. The two teams are engaged in fieldwork and laboratory studies in a comparative analysis of the relations among art, technology, and style in Precolumbian America and Precolonial Africa. The Hosler-Cummins team works in Ecuador and Peru, the Childs-Dewey team in Zaire and Zimbabwe. Professor Heather Lechtman, CMRAE director (MIT, Anthropology/Archaeology and Materials Science and Engineering), is coordinator of the project.

The subject of the Center's graduate offering was Materials in Ancient Societies: Fauna taught by Dr. Richard Meadow (Harvard University) and Dr. Bryan Gordon (Canadian Museum of Civilization, Ottawa). An entire month was devoted to the study of incremental growth structures in animal teeth by thin section analysis, a new and promising technique which the CMRAE Graduate Laboratory is especially well equipped to develop. In addition, three graduate students at the Center, two from Boston University and one from Brandeis University, continued their full-time research towards the doctoral degree. Their dissertation research is diverse in scope, including: standardization and control of ceramic production in the ancient Mexican capital of Teotihuacán; analysis of the ceramic production of Early Neolithic societies of southern France, as they moved from hunting and gathering to primarily agricultural subsistence economies; the technology of Proto-historic pottery in northwest Iberia. All three students carry out their laboratory analyses and experiments in the CMRAE Graduate Laboratory.

Dr. Suzanne De Atley, CMRAE Visiting Scientist, continued to shepherd the NSF-funded archaeological ceramics atlas project through the final stages of manuscript preparation. The atlas will provide the archaeological profession with a set of annotated microstructures of low-fired ceramic materials studied petrographically and tested at the Center. During her year of fieldwork in Ecuador, Dr. Hosler found time to participate in the ongoing joint research program between CMRAE and the Banco Central del Ecuador whose goal is to document the prehistoric metallurgies that developed in the region. Her efforts concentrated on the vast collection of metal artifacts in the Museo Antropologico, Guayaquil and in training the staff of that Museum's laboratory in the procedures of artifact sampling and analysis.

HEATHER LECHTMAN

Integrated Studies Program

Introduction

The Integrated Studies Program is designed especially to appeal to students who are interested in the place of science and technology in the world around them. Now in its fourth year, ISP has continued to explore science and technology-related issues alongside freshman year requirements.

Statistics

The ISP enrollment was close to our preferred enrollment of 35-40 students. Consistent with enrollment patterns of past years, we included more women and minorities than the MIT average, and several international students. In 1987-88, the total of 29(Fall)/33(Spring) students included 13/17 women (45/52%), 6/10 minorities (21/30%), and 5/5 internationals (17/15%). Overall, while we do not make systematic comparisons of students in ISP with those in the other freshman programs or in the curricular mainstream, ISP students tend to match the performance of the average freshman class.

Faculty and Staff

The faculty and staff continuously associated with the Program include Professor Leon Trilling, Professor Merritt Roe Smith, Professor Louis L. Bucciarelli, and Ms. Anne Armitage. This year Senior Research Scientist and Senior Lecturer Alan Lazarus joined ISP as resident physics instructor, and C.L.E. Moore instructor Douglas Ulmer joined us from the Department of Mathematics as calculus instructor. In addition, ISP has been extremely fortunate in a long-standing association with Professor John B. Vander Sande for our 3.091 recitation.

Curriculum and Development

We have maintained our reliance on mainstream lectures combined with an integrative supporting framework provided from within ISP: our students attend regular mainstream lectures in calculus, physics and chemistry, but attend recitations, some humanities offerings, seminars and other special events designed for them within ISP.

This year the single humanities subject formerly required of ISP students each term was replaced by an assortment of recommended subjects. To provide a unifying humanities-based activity for ISP students, we offered a single seminar, "The Arts, Science, and Technology," which received a strong endorsement from participants, both speakers and students, who recommend we continue similar activities. In addition, we continued our collaboration with the Knight Science Journalism Fellows, who served as mentors for students participating in our IAP activity, "Science Journalism: Writing Feature Articles."

In 1988-89, we will enter a new stage in our evolution as a program. Professor Arthur Steinberg, of the Anthropology/Archaeology Program, will become Director of ISP. As we go to press with this report, we are developing a new ISP Humanities subject "Cultures and Technologies" with an integral laboratory component, to be offered as a single 12-unit subject each term.

Several times in the last two years the staff has discussed the possibility of a core hands-on experience for freshmen. This two-semester subject will include laboratory modules in cooking, weaving, blacksmithing, clock-making, engine repair, and computer disassembly and re-assembly. Running alongside class readings and discussions, these modules will serve as windows on technologies in different eras and cultures. In addition, Dr. Lazarus is designing laboratory units in physics to accompany 8.01 and 8.02. We anticipate that this combination of activities, related both to humanities and science subjects, will deepen the ISP students' understanding of how the science and engineering that they will be engaged in fit into their own society.

In closing, the staff of ISP would like to express our deep affection and gratitude to Professor Trilling, who first recognized the need for such a program at MIT, and who gave us truly selfless support for four years.

ANNE ARMITAGE

INTRODUCTION

The Statistics Center was established in 1981 to provide educational and research opportunities for students and faculty interested in statistics. The academic staff of the Statistics Center is drawn mainly from Mathematics, the Sloan School of Management, and Economics. The Statistics Center is under the direction of Professors Daniel McFadden and Roy Welsch. Approximately ten graduate students were enrolled in master's and doctoral degree programs. There are ten faculty affiliated with the Center, two principal research scientists, and three research scientists.

RESEARCH ACTIVITIES

Statistics

We will briefly summarize ongoing research in Statistics:

Dr. Mai Zhou, an instructor in Applied Mathematics, is working on finding a two-sided bias bound for the Kaplan-Meier estimator and is investigating the asymptotic normality of a synthetic data regression estimator for censored survival data.

Dr. Greta Ljung, a visiting associate professor in Applied Mathematics, has continued her work in time-series analysis with special emphasis on diagnostic testing, Lagrange multiplier tests, and estimation of missing observations.

Dr. Mendel Fygenon, a new instructor in the Department of Mathematics, joined the Statistics Center this year. He is working on the efficient estimation of the parameters in semi-Markov processes with applications in biology.

Professor Richard Dudley of Pure Mathematics, is working on the theory of empirical processes. He has also developed a new test for multivariate normality and is continuing his work on genotype-environment interactions.

Dr. Peter Kempthorne, an associate professor of Management, is working on four principal research topics: filtering information from multiple sources; statistical modeling in finance, statistical decision theory, and influence analysis in regression.

Mr. Alan Zaslavsky, a research associate at Harvard and a doctoral candidate in the Department of Mathematics at MIT, has continued his work in quality control and on statistical techniques for representing census undercount by reweighting of households.

Professor Roy Welsch has continued his work on nonlinear regression estimation for exponential family models (with Dr. David Gay at Bell Laboratories) and on computer guided statistical diagnostics (with Mr. Achilles Venetoulas and Professor David Belsley at the MIT Center for Computational Research in Economics and Management Science (CCREMS)). These projects have been funded by the US Army and the National Science Foundation.

Professor Welsch has begun working with Dr. Alexander Samarov at CCREMS on recursive and moving window diagnostics. The moving window technique allows the detection of model failure and coefficient shifts by watching how estimated coefficients change as a fraction of the data (say 25%) is used in a sequential window moving with an ordering obtained either from time or from one of the explanatory variables. There are important applications to quality control. Lisa Newton (Statistics Center) has been helping with this work. This project is funded by the National Science Foundation.

Professor Welsch is also working with Professor Kempthorne on models for assessing credit risk at financial services institutions. This project will build upon previous research in diagnostics, robust estimation, and logistic regression.

Professor Samprit Chatterjee spent his sabbatical from New York University at the Statistics Center. He continued his research on sensitivity analysis in regression.

Econometrics

Housing decisions of the elderly have been investigated by a research group led by Professor McFadden. Working with the Panel Study on Income Dynamics and the linked tapes of the Annual Housing Survey, this group has investigated the questions of the transactions costs faced by the elderly, the prevalence of "liquidity traps" in which the elderly are "house-rich and cash-poor", and the heterogeneity of tastes. Henry Pollakowski has carried out calculations of hedonic prices for housing by region and time. Douglas Staiger and Edward Norton are compiling data on nursing home availability and costs. Brian Palmer has worked on continuous-time models of mobility. Johanthan Feinstein and Professor McFadden have estimated heterogeneous Markov models of mobility and tenure choice. This research has produced several papers presented at National Bureau of Economic Research conferences on the economics of aging, and additional research reports are in progress.

Professor McFadden has been doing research on methods of simulated moments estimation for computationally intractable problems, along with research assistants Dan Nelson and Chunrung Ai. Professor Henry Farber has been using Statistics Center computing facilities in continuing investigations of the duration of unemployment. McFadden has also been developing statistical methods for estimating the parameters in dynamic stochastic programming models of choice behavior.

Professor Danny Quah, Assistant Professor in Economics, has been carrying out studies of the behavior of macro-economic time-series, with particular attention to international linkages. He has installed the Regression Analysis of Time Series software at the Statistics Center.

Concurrent Computing

The Concurrent Computing Group consists of Virginia Klema and associated students.

During the past year work has continued on building a hardware/software environment to support research on numerical algorithms and scientific applications in a concurrent computing environment. In particular we have focused on three distinct machine architectures from the point of view of supplying an environment that permits the user with a scientific application to design top-down specifications that can be transported among the three systems.

The hardware available for this research within the Concurrent Computing Laboratory includes: a number of custom built "manager-worker" concurrent systems, a 32-node Intel hypercube, and a small Bolt, Beranek and Newman (BBN) Butterfly development system on loan from BBN. A SUN 260/C is a communication device, a file server and graphics engine for the concurrent environment. Two additional SUN 3/50's complete the inhouse resources of the Concurrent Computing Laboratory, all nodes of which are linked together via a local area network. A key characteristic of the hardware from the point of view of this research is that all nodes, whether network nodes, system hosts, or elements within the concurrent systems, support the Institute of Electrical and Electronic Engineers (IEEE) standard for binary floating point arithmetic in hardware. For testing and evaluation of larger problems, we have been given access to large Butterfly machines as well as an 8-processor TX Alliant.

Although all configurations within the laboratory are tightly coupled, multiple instruction multiple data, homogeneous systems, they exemplify three distinct architectures: shared memory with Banyan network interconnect (BBN Butterfly), private memory with hypercube interconnect (Intel Hypercube), and dual-ported memory with multibus interconnect (manager-worker systems). Moreover, they encompass two distinct programming paradigms: coordination of cooperating sequential processes with communication via message passing, and generation of computational tasks as required with management of common memory.

Ongoing research toward the development of an appropriate supporting environment to serve these diverse architectures continues at both the node library and operating system interface levels. The basic linear algebra modules that form the basis for higher level mathematical software and that are suitable for use in the various node libraries are being designed and implemented. Trap handlers for error recovery in the event of arithmetic exceptions are being developed, as are the mechanisms for generating error reports and debugging information. Strategies for node-node, host-node and node-host communication and monitoring also provide an active area of research.

As our research progresses, the resulting environment is tested within the context of two distinct classes of scientific applications: one is that "parallel certain" as exemplified by many computationally intensive statistical methods, and another such as the algorithms used in computational fluid dynamics in which the algorithmic decomposition strategies are less obvious.

STATISTICAL COMPUTING

Dr. Ross Ihaka joined the Statistics Center in February as a Research Associate. He is working closely with Project Athena on the development and acquisition of statistical software for Athena workstations. In preparation for the adoption of S by project Athena he wrote a graphics device driver running under the X version 11 windowing system. The software is currently undergoing testing at the University of Toronto (Rob Tibshirani) and at Bell Labs (Alan Wilks). The software consists of over 1000 lines of C code. Dr. Ihaka is also in charge of all statistical computing at the Statistics Center.

In addition, Dr. Ihaka is writing a paper on a technique for the estimation of physical parameters associated with earthquakes. The technique uses a variant of maximum likelihood to estimate the parameters under a stochastic model for the effects of wave scattering in the lithosphere.

SEMINARS

The following major seminars were given this year:

Professor Brian Ripley from the University of Strathclyde, United Kingdom, gave a talk entitled "Uses and Abuses of Simulation." Professor Peter Hall, Visiting Professor at Brown University and Australian National University, gave a talk entitled "Bootstrap Resampling and Iteration: The Russian Doll Principle." Professor Terry Marsh, University of California at Berkeley, gave a lecture on "Trade Activity and Price Behavior in the Stock and Stock Index Futures Markets in October 1987." Professor Andrew Siegel, University of Washington, gave a talk entitled "Optimal Hedging of Delivery Risk in Futures Markets." Professor John A. McDonald from the University of Washington, gave a talk on the Cactus system, which is implemented in CLOS, a proposed standard object-oriented extension of Common Lisp.

The Statistics Center also had the following Independent Activities Period (IAP) schedule:

"The S Statistical Computing Language for Data Analysis, Graphics, and Matrix Calculations,," Alan Zaslavsky – January 8.

"New Developments in Statistical Graphics," Roy Welsch – January 11.

"Life on The Street After The Crash: Views On Programmed Trading," William Krasker – January 12.

"Macro-Economic Forecasting: Has It Improved?," Stephen K. McNees – January 14.

"Scenes and Impressions Of Present-Day China," Nicholas Lange – January 19.

"The Census Undercount," Alan Zaslavsky – January 20.

"Quantitative Methods In Investment Banking," Tony Wong – January 21.

"Chaos and Equilibrium: Portrait In X11," Lisa Newton – January 25.

"Response Surface Experimental Design," Mendel Fygenon – January 29.

FUTURE DIRECTIONS

The Department of Mathematics was successful in its search for a new senior mathematical statistician. Professor Peter Huber will leave the Department of Statistics at Harvard in July to join the Department of Mathematics and the Statistics Center. This will greatly strengthen our program.

The search for a new senior statistician to be supported equally by the Departments of Management and Economics was not successful and will be continued next year.

We also plan to begin a search for a statistician interested in quality control and experimental design to work with the Leaders in Manufacturing Program.

The Statistics Center is going to help Professor Steven Lerman of Civil Engineering develop a new statistics subject for engineering students. We hope that this will lead to greater interaction with the School of Engineering.

**DANIEL MCFADDEN
ROY E. WELSCH**

The academic year 1987-1988 was the fourth full year of operation of the Program in Women's Studies. The program continues to offer a strong interdisciplinary curriculum taught by a dozen faculty members from ten departments. Its solid base of student interest was evidenced this year by exceptionally high enrollments. Professor Ruth Perry, founding director of the Program in Women's Studies, who was awarded tenure as a full professor effective July 1, 1987, was succeeded as Director in January 1988 by Associate Professor Isabelle de Courtivron of the Foreign Languages and Literatures Section. Ms. Barbara Schulman was appointed Coordinator of the Program effective January 1988.

Curriculum

Eleven courses, one undergraduate seminar, and two sections of larger multi-sectional courses were offered by the Program in Women's Studies during 1987-88. Total enrollments exceeded 350 students, a 75 percent increase over last year's figures. "American Women's History," taught by Assistant Professor Sarah Deutsch enrolled 39 students. In future, this subject will be taught annually as part of the core History curriculum. Professor Susan Carey (Cognitive and Brain Science) taught "Psychology of Gender," which enrolled 84 students. Professor Jean Jackson's "The Contemporary Family," based in the Anthropology/Archaeology Program, drew 41 students. Both this subject and "Introduction to Women's Studies," taught by Professor de Courtivron, were granted HASS-D status. Given the increasing intellectual sophistication of the students who take "Introduction to Women's Studies", and because it represents the first tier of our new minor, it will henceforth be taught in collaboration with a half-dozen faculty across disciplines. "Reproductive Biology," co-taught by Professor Nancy Hopkins (Biology) and Senior Lecturer Caroline Whitbeck (Mechanical Engineering), a subject which grounds scientific and technological discussions of reproduction in their ethical, social and political contexts, is being considered as a Context Course for the 1988-89 academic year. "Current Issues in the Women's Movement," a new advanced subject in which students pursue independent research and field work, was co-taught by Professor Louis Kampf and Lecturer Joni Seager, and enrolled 25 students. Student evaluations affirmed the importance of such a course to the Women's Studies curriculum.

Although we have lost several faculty members who previously taught in the Program, several new subjects will be added to next year's curriculum. Our second advanced seminar, "Contemporary Issues in Women's Studies," a rotating topics subject, will be taught in Spring 1989 by Professor Jill Conway, former President of Smith College and a Visiting Scholar in STS. Professor Conway's theme will be "Issues in Modern American Feminism: Gender, Work and Politics." "Black Women Writers: Texts and Critics," taught by Professor Marilyn Richardson of the Writing Program, will be offered for the first time in Fall 1988. A new subject on gender and planning in the Third World will be offered by Lecturer Gillian Hart through the Department of Urban Studies and Planning during Spring 1989. The subject evolved out of a very successful two day-conference entitled Gender and Planning which was organized by the DUSP Women in Planning group in April 1988. Funding for the conference came in part from a Ford Foundation grant received by the MIT Program in Women's Studies, along with women's studies programs at ten other eastern region universities, to help integrate gender into the curriculum. Also funded by the Ford grant was a Gender and Science Faculty Workshop Series, coordinated by Senior Lecturer Whitbeck, which met monthly with invited speakers to examine new models of incorporating gender analysis into the participants' fields.

Initial planning for new subjects in DUSP and in Art and Architecture to be cross-listed with Women's Studies are underway and should be solidified in the fall. One of the Program's priorities is to continue to broaden its base outside of the humanities and social sciences, the fields from which it draws its strength on most other campuses.

In 1987-1988, an undergraduate seminar entitled "Violence Against Women: A Social and Cultural Heritage" was taught by Instructor Ann Russo both semesters, in an effort to encourage students to address issues of major concern in their lives within an educational context. Next fall this seminar will be funded by the Associate Provost, the Dean for Undergraduate Education, Professor Sheila Widnall, and the Dean for Student Affairs.

Finally, a minor in Women's Studies was approved, to become effective in Fall 1988.

Students

At the end of the school year, Women's Studies had 15 concentrators and three majors. A UROP student worked with Women's Studies faculty to compile a bibliography of materials relating to Black women in the United States. The completed project will be an important addition to the series of bibliographies compiled by the Program over the past several years and which provide a useful resource for Women's Studies scholars and students.

Resources

The Women's Studies Reading Room continues to be heavily used and the collection is growing rapidly. It now includes over 2000 titles and 40 journals. Beginning in Fall 1988, Women's Studies headquarters will acquire additional space adjacent to its current offices, but will no longer be housed within the Humanities Library; access to the program will be established via Building 14N. The Women's Studies Reading Room, the intellectual center of the Program, will continue to be located within the Library.

In May 1988, MIT's Women's Studies program organized a Boston-wide meeting of Women's Studies administrators and directors. This meeting resulted in the formation of an association, which will continue to share information and resources more formally and to explore possible avenues of collaboration. The MIT Program in Women's Studies agreed to increase its production of the "Women's Studies Around Boston" newsletter from once to twice per semester.

Thanks to alumnae donations, for the second year in a row, the Program offered undergraduate writing prizes in the areas of fiction, poetry and expository writing.

Programs and Special Events

During the Fall, the Program co-sponsored a series of public readings by renowned writers Grace Paley, Toni Cade Bambara and Jamaica Kincaid. In the Spring, a lecture series featuring distinguished scholars whose work has had a major impact on their respective disciplines was organized in collaboration with other MIT programs. Professor Olwyn Hufton, European historian and Head of the Women's Studies Program at Harvard, lectured on Gender and the French Revolution; Barbara Bergman, economist from the University of Maryland, spoke on the effects of equal opportunity legislation on Blacks and women; and Kay Warren, anthropologist and Head of the Women's Studies Program at Princeton gave a lecture on "Gender, Technology and Development." The Program sponsored numerous other events, including a well-attended forum on child sexual abuse and the media; a lecture on feminism in the Third World; presentations by international visitors on the status of women in their countries; and several film screenings. Finally, we co-sponsored two highly successful programs: a lecture series on Women and Politics organized by the Department of Political Science, which will continue next year, and the Gender and Planning Conference mentioned above.

Next year, our programming activities will include several Black women literary critics and lectures on women and planning in the Third World, in conjunction with the two new courses offered with, respectively, the Writing Program and DUSP. Additionally, Women's Studies will premiere several new films by women in a screening series on women, community and sexual politics, as well as sponsoring speakers in the area of gender and science.

Research and Publications

Women's Studies faculty contributed actively to their fields this year. In November, Professor Deutsch saw the publication of her book, No Separate Refuge: Culture, Class and Gender on an Anglo-Hispanic Frontier in the American Southwest, 1880-1940, by Oxford University Press. Professor Deutsch also received several awards and honors this year, including an MIT Career Development Chair, and a National Humanities Center Fellowship in North Carolina. Professor Edith Waldstein's book, Bettina von Arnim and the Politics of Romantic Conversation, was published by Camden House. Professor de Courtivron chaired the Commission on the Status of Women of the Modern Language Association, and published two articles on French women writers. Professor Margery Resnick organized a conference on "Women and Violence" at the International Institute in Spain.

ISABELLE DE COURTIVRON

SLOAN SCHOOL OF MANAGEMENT

In the 1987-1988 school year the MIT School of Management focused on generating a strategic vision of where it wanted to go in the next decade. Three elements became central in this vision.

Because foreign firms are now the technological equals of American firms, American firms no longer operate behind a safety barrier of superior technology. As a consequence both foreign and American general managers have to be on top of technology in a way that was not necessary in the past. The Sloan School seeks to be a leader in learning how managers can stay on top of technology.

Economic growth, government decisions, and computer-telecommunications technology have created a world economy. As a result international dimension of management has become part of general management rather than a narrow specialty. There are no American managers even if a manager spends his whole career geographically inside the United States. Everyone is a world manager. The Sloan School seeks to educate those world managers be they American or foreign in national origin.

Because of the development of a world economy, changes in the demographics in the work force (more women, minorities, other nationalities) and new techniques of participatory management, organizations are going to have to change in fundamental ways. The MIT School of Management seeks to learn how organizations must change to cope with this new environment and how these organizational changes can be implemented.

What follows is a report on the current program of the school and its first steps to implement its new strategic direction.

TEACHING PROGRAMS

Undergraduate Program

The second class in the new undergraduate program in Management Science graduated this spring. Of the 64 graduating seniors, twenty-two chose an option in Information Systems, 6 selected Marketing Research, 7 chose Operations Research, and 6 selected Behavioral Science. The remaining twenty-three students followed other specially approved options.

Eight of our graduates also received bachelor's degrees from the Department of Electrical Engineering and Computer Science, four from the Department of Mechanical Engineering, two from the Department of Mathematics, and one each from the Department of Chemical Engineering and the Department of Political Science.

As can be seen from Figure 1, the introduction of the Management Science curriculum four years ago has been accompanied by a significant increase in undergraduate enrollment at the School of Management. One hundred twenty-three students were enrolled this spring, in addition to 24 others who were enrolled in Management Science as their second SB department. (Enrollment figures are based on the Registrar's fifth-week counts.)

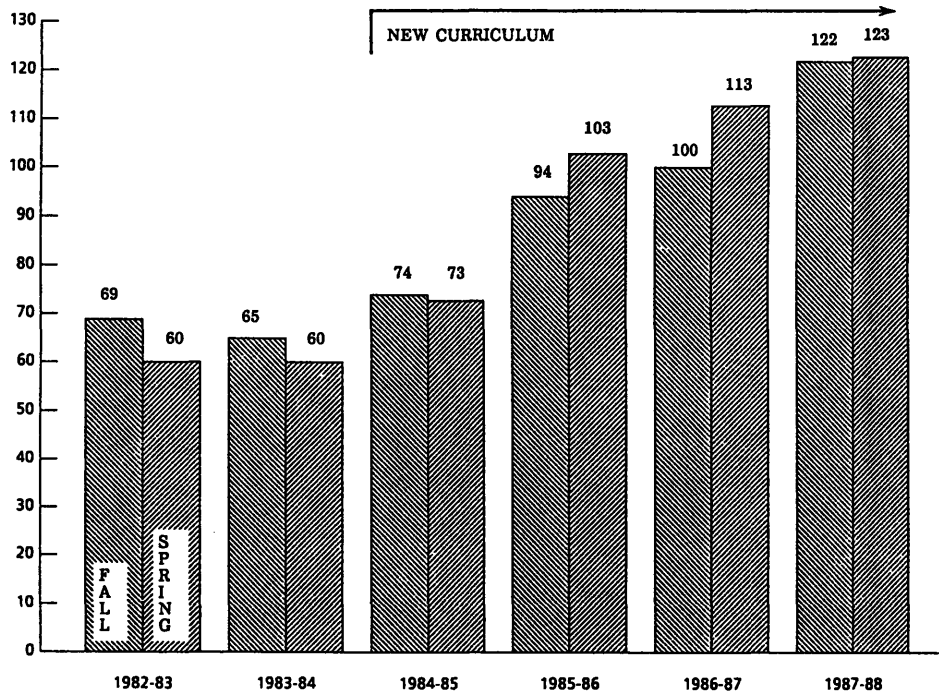


Figure 1

Fall and Spring Undergraduate Enrollments
1982-83 through 1987-88

Fifty-four of our continuing undergraduates have declared their options as follows:

Regular Options

Information Systems	21
Operations Research	1
Marketing Research	9
Behavioral Science	8

Special Options

Finance	14
International Management	1

Total Declared 54

Figure 2 indicates a substantial number of students from other MIT degree programs enroll in our undergraduate subjects. There were 522 such enrollments during the 87-88 academic year, representing the classroom equivalent of 57 full-time Management Science undergraduates. Since an undergraduate actually takes only about 60 percent of his or her units in management, this is equivalent to having approximately 95 additional undergraduates in our program.

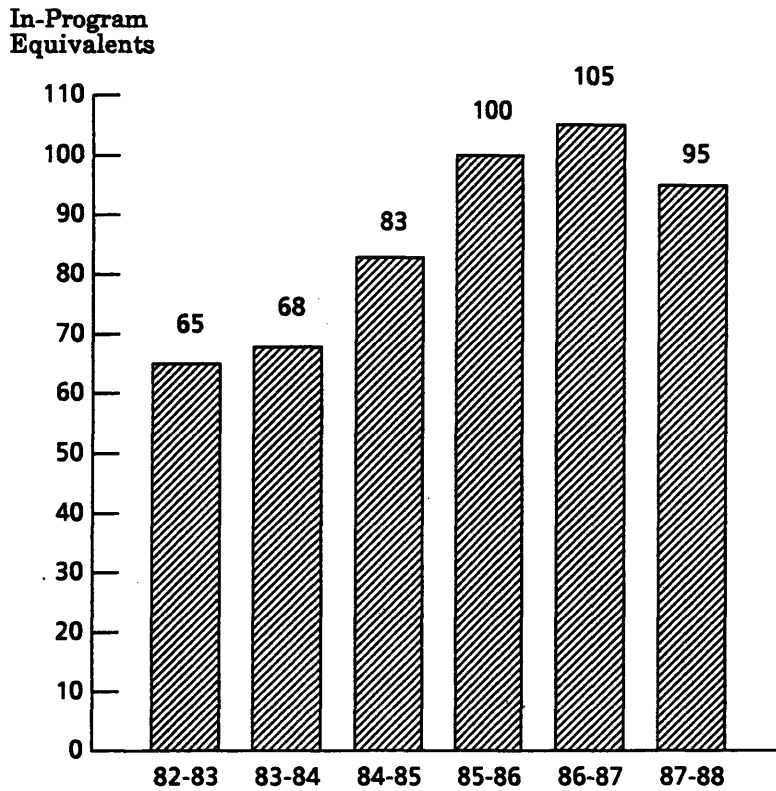


Figure 2

MIT Students in Other Degree Programs
Enrolled in Undergraduate Management Subjects
1982-83 through 1987-88

Faculty participation in MIT's Independent Activities Period (IAP) in January has been steadily increasing each year. This year, 43 percent of the Management faculty participated. Faculty participation has almost quadrupled since 1983.

Increased enrollment required enlarging the Undergraduate Program Committee to provide more faculty advisors. Professors Thomas J. Allen, Robert M. Freund, Steven C. Graves, John C. Henderson, Frank R. Kardes, Lode Li, Thomas W. Malone, James B. Orlin, and Abraham J. Siegel, Drs. Stan N. Finkelstein and Jeffrey A. Meldman, and Ms. Hillary De Baun served as undergraduate advisors. Professor John D. Sterman served as coordinator of MIT's Undergraduate Research Opportunities Program, (UROP). Dr. Meldman chaired the Undergraduate Program Committee and served as coordinator of the School's IAP activities.

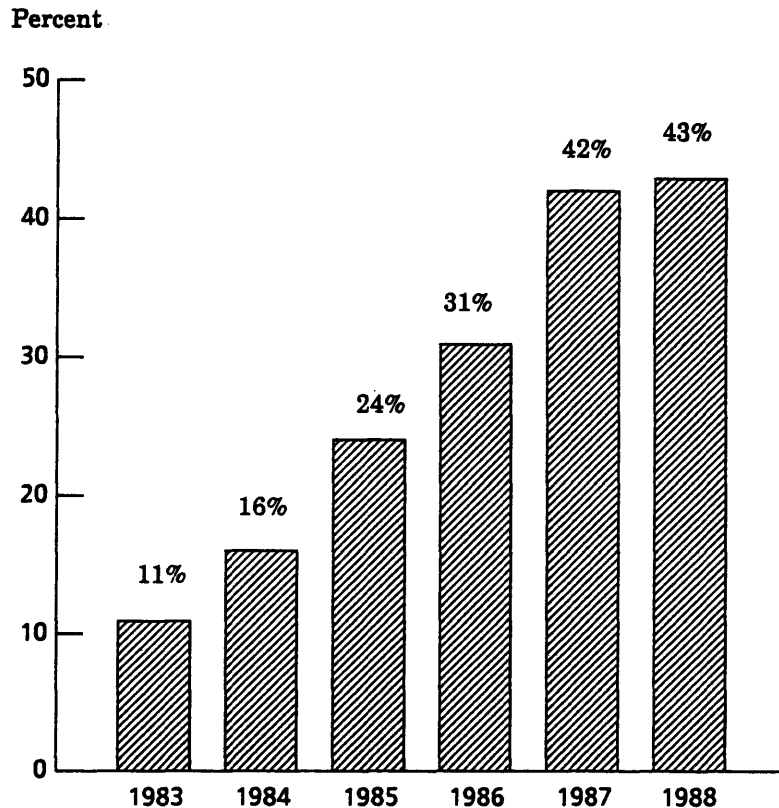


Figure 3
 Participation of Management Faculty
 in MIT's Independent Activities Period
 1983 through 1988

Master's Program

The master's core curriculum has clearly achieved the goals the faculty established for it in 1984. However, as the mission of the MIT School of Management has been the focus of much effort and attention this past year, we can expect that the core will, in the next year, become the focus of similar attention. The completion of the mission strategy will call for a reconsideration of the core to implement this strategy.

The School continued to provide many opportunities for major business leaders to address the community. The Distinguished Speakers Series had a very successful year, hosting Samuel W. Bodman, President and Chief Operating Officer, Cabot Corporation; Tom H. Barrett, President and Chief Operating Officer, Goodyear Tire and Rubber Company; and P. Roy Vagelos, Chairman and Chief Executive Officer, Merck and Company. In addition, with the MIT Center for Technology, Policy and Industrial Development, the Distinguished Speakers Series co-sponsored the visit of Vittorio Ghidella, President, Fiat Auto. Speakers are chosen and hosted by a board of master's students. The Business Forums, also organized by a student board, held two highly successful panels. The topic of the fall session was Business Ethics, while the spring session was titled World Trade.

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 Jeremy M. Cohen, James Elkind, Sean T. Enright, Mark D. Friedman, and Elana T. Lichtenthal. Lambros Anagnostopoulos, Phillippe A. Frangules, and Michael Lavdas received Latsis Scholarships through a program established by Dr. Spiro J. Latsis and his family to provide fellowship assistance to talented graduate students of Greek descent. Our first-year students were again eligible to apply for scholarships offered by corporations to MIT School of Management students and based upon academic performance and involvement in school activities. The Unisys Corporation awarded their scholarship to Kolleen E. Karney, and the Digital Equipment Corporation scholarships were bestowed upon Linda L. Archer and Carol A. Naslund.

Several second-year master's students received special awards for academic excellence and professional promise. The MIT School of Management was proud to name Thomas M. Pounds as the second Miriam Sherburne Scholar. This scholarship was established by the alumni/ae of the School in recognition of Miss Sherburne's more than 50 years of devoted service. The Henry Ford II Scholarship, established by the Ford Motor Company in 1978, was this year awarded to Terence C. Burnham. Robert E. Kennedy and Karen E. Randig were chosen as the Mr. Martin Trust SM '58. This year's recipient of the Henry B. du Pont III Scholarship was Charles S. Boulas. The award was established by the Crestlea Foundation with a gift from the late Mr. du Pont. Stephen P. DeFalco was named the Alexander Proudfoot-Howard J. Samuels Memorial Fellow for 1987-88. This award is given annually by the Alexander Proudfoot Company in honor of Mr. Samuels, a former Proudfoot director and longtime friend of MIT. The Thomas M. Hill Prize was established by the late Professor Hill's friends and colleagues to honor his memory and his 30 years of distinguished service to the Sloan School. This year's winner was Laurence J. Nath. Lesley S. Nash was named as the first George Henning Scholar, an award established this year by Mrs. Henning in her husband's memory.

Michael F. Falvey and John F. Krafcik were named the 1987-88 Seley Scholars, awards established by the late Louis E. Seley and Mrs. Seley to honor graduating master's students for outstanding academic achievement and exceptional promise of business leadership. The Brooks Prize was established by E. Pennell Brooks, first Dean of the Sloan School, to honor the author of the best master's thesis. The winner for the 1986-87 academic year was Richard C. Ocken; his thesis, "A Mathematical Programming Technique for Scheduling Courses at the Sloan School," was supervised by Professor Charles Fine. Honorable mention was awarded to Amy L. Reis for her thesis entitled "A Study of the Performance of High Yield Bond Funds," which was supervised by Professor Patricia O'Brien.

Nine second-year master's students won the 1988 General Motors marketing competition, besting teams from nine other business schools. The Sloan School team had the challenge of developing a marketing and advertising campaign for the 1988 Pontiac LeMans couple. Entries were judged on a written treatise and an on-campus presentation.

The number of applications for admission increased yet again this year. We brought in 181 students in the entering class, similar to the number of new students for the previous year. The following table presents a profile of the graduating classes of 1988 and 1989.

Profile of Graduating Master's Classes	1988	1989*
Number of Candidates	186	181
US Citizens	131	127
Foreign Citizens	55	54
Women	38	33
Members of Minority Groups	13	13
Median GMAT Score (national average is approximately 460)	660	650
Undergraduate Grade-Point Average (out of 5.0)	4.4	4.4
Undergraduate Majors		
Social Sciences and Humanities	33%	32%
Physical Sciences	16%	12%
Engineering	38%	40%
Pre-Professional	13%	16%
Average Years Full-Time Work Experience	3.7	4.0
Age at Admission		
Under 23 years	8%	4%
23-24	27%	33%
25-26	28%	25%
27-28	20%	14%
29 and over	17%	24%

*Projected

Despite a traumatic beginning brought on by the October 19 stock market crash, Sloan School master's students fared well in the job market this season. By July 1, more than 84% of the Class of 1988 had accepted employment. Overall, placement results indicate a continuation of last year's movement toward manufacturing firms and away from service organizations. This year 33% of the class entered manufacturing companies, compared with 28% in 1987 and 26% in 1986.

In terms of job function, the largest number of students chose financial roles (31%, down from 42% in 1987). Consulting/project management (25%) and marketing (17%) came next in popularity. While Boston and New York continued to attract a high percentage of students (22% and 21%, respectively), emerging high technology firms drew a record number of people to the West Coast (16%).

As for industrial affiliation, consulting led the way by a significant margin at 24% of the class (up from 20% in 1987). The electronics industry came next at 13%, followed by investment banking and computer services/software at 10% each. Most noteworthy here was the major drop in investment banking hires, down from 25% of last year's class.

Base salaries for 1988 graduates ranged from \$25,000 - \$95,000, with a mean of \$53,000. This represents a 5% increase over last year's salary figures. Of equal significance is the fact that students received an average of three offers, giving them options to choose from in selecting their final career opportunities.

The Master's Program Committee, chaired by Professor Thomas A. Kochan, continued its refinement of the master's core and began to address how the program might change as a result of our new mission statement. Dr. Jeffrey A. Barks, Associate Dean for Master's and Bachelor's Programs, again provided effective administrative leadership for those programs. Margaret Daniels Tyler directed our admissions effort with flair, making the task of attracting and evaluating all those applicants look much easier than it is. David A. Weber, Director of Master's Student Services, continued to provide sound advice and counsel to our students in selecting their programs and in organizing their extracurricular activities. Lucinda M. Hill, Coordinator of the Master's Program and Master's Alumni/ae Relations, considerably strengthened our effort in alumni/ae relations as well as provided superb service in her other administrative responsibilities. Miriam Sherburne and Harriet Barnett continued to help the master's program as part-time advisers, counseling students, meeting prospective degree candidates, and evaluating applications. Miss Sherburne officially retired at the end of the year but will continue to help us with registration and other student-related matters during critical parts of the academic year. Linda Stantial, Director of Master's Placement, continued to develop and refine a very high level of service that we provide to our students in career counseling and placement. Grace Locke joined the Master's Program Office as assistant to Dr. Barks while continuing as assistant to Professor and former dean Abraham J. Siegel.

Alumni/ae Relations

The alumni/ae relations program has prospered under the joint leadership format established last year. Jeffrey A. Barks, Associate Dean for Master's and Bachelor's Programs, holds responsibility for the alumni/ae of the master's, bachelor's, and doctoral programs, while Alan F. White, Associate Dean for Executive Education, maintains responsibility for the alumni/ae of all executive education programs.

The Sloan Club, the national organization representing master's and doctoral program graduates, again this year presented a wide variety of programs and services to Sloan alumni/ae through the efforts of the regional chapters. Sloan Club activities are open to alumni/ae from all Sloan programs, and events are often sponsored jointly with local MIT clubs or alumni/ae groups from other business schools. Sloan Club activities run the gamut from breakfast talks to lecture presentations to strictly social activities. Club members also serve the School, for example, with their involvement in admissions recruitment activities and summer placement for first-year students. The national board of the Sloan Club meets three times during the year to share ideas and support among regional chapters and to discuss ways to better serve both the alumni/ae and the school.

The reunions for the fifth, 10th, and 25th year master's classes, held June 4, were a great success, with a dinner in the MIT Faculty Club highlighting a weekend full of events. The Eighth Annual Summer Gatherings drew large crowds in New York, Boston, and San Francisco, and a Fall Gathering is again scheduled in Washington, D.C., where last year's thunderstorm could not deter an enthusiastic group. A directory of all Sloan graduates--including, for the first time, those from the Bachelor's program--was published this winter, making current information available to all alumni/ae.

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, President of Sun Refining and Marketing Company (President); Richard J. Santagati '79, Chief Executive Officer of Gaston Snow & Ely Bartlett (Vice President); and Ronald L. Turner '77, President-Electronic Systems Division of the Singer Company (Secretary/Treasurer).

The MIT Society of Senior Executives was established last fall, building on strong interest expressed by program alumni/ae. The first two-day Convocation, on "Global Management Strategies in an Uncertain World," is scheduled for October 1988, and features as keynote speakers: French Prime Minister, Michel Rocard; Arthur D. Little CEO, Charles LaMantia; and Sloan School Dean, Lester Thurow. The first Board of Governors was formed. John DesBarres F'84, President and CEO 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 C31 Systems, Grumman Data Systems, serves as Secretary.

All interested alumni/ae were invited to an open meeting in February with Dean Lester C. Thurow, for a dialogue regarding the new mission and strategy for the School. Dean Thurow also detailed his plans in an article in SLOAN, the School's alumni/ae magazine. This year's spring edition gave notice of the magazine's move to expand and modernize--the magazine will publish three editions each year, under the new name MIT MANAGEMENT.

Alumni/ae relations at Sloan continue to expand as the School works to strengthen the connection with its alumni/ae body.

Management of Technology Program

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.

Program structure and a new curriculum were developed originally by a joint faculty committee from both the Sloan School and the School of Engineering. The curriculum included an intensive core of analytic subjects taken during the summer and at least eight subjects allowing intensive study of the management of technical people and programs. All program attendees also write a thesis in the area of the management of technology, and company-sponsored individuals in particular find the thesis a golden opportunity to explore in great depth some issues of chief corporate concern.

The Management of Technology Program was conceived originally by the Faculty Program Chairman, Professor Edward B. Roberts, of the Sloan School and the late Herbert Hollomon, Professor in the MIT School of Engineering. From a pilot class of six students, the program expanded to 27 for the 1987-1988 class. Plans are to continue expanding gradually toward about 50 students per year. Though required to have at least five years of work experience before coming to the program, students average closer to 10-12 years of experience and tend to be in their mid-30s in age. They come from a wide variety of fields, including aerospace, electronics, research and development, and the military. About one third of each class has been foreign, with representation from several countries in Europe, also Argentina, China, Israel, Japan and Singapore. Most students are financially supported in the program by their organization.

Two curriculum additions enhanced this part year's program: (1) the Seminar in Management and Technology, a weekly experience-sharing seminar with senior general and technical executives; and (2) a one-week January field trip to the Research Triangle area of North Carolina and to the Orlando/Cape Kennedy area of Florida, to visit research and manufacturing facilities and engage in more intensive on-site executive interviews.

Discussions have been underway during the past several years with faculty of both schools regarding addition of a mid-career Management of Manufacturing Systems track to the MOT Program. It is hoped that new subjects can be developed that would permit initiation of this option in June 1989. This would complement within the Executive Education Programs the new Leaders for Manufacturing Program launched this past year for entering graduate students.

The PhD Program

During 1987-88, the Sloan School's doctoral program maintained its prominent position in the face of continuing intense competition from the other leading business schools. From a record breaking 350 applications, we made 30 admission offers and had 17 acceptances, which were widely distributed across our 13 concentrations:

Managerial Economics	2 (1 foreign male, 1 US male)
Finance	3 (2 foreign male, 1 US male)
Accounting	1 (1 US male, 1 US female)
Management of Technological Innovation	1 (foreign male)
Strategy & Policy	1 (foreign male)
Organization Studies	2 (1 foreign male, 1 US female)
Marketing	2 (1 foreign male, 1 US female)
Operations Management	2 (1 US male, 1 US female)
Operations Research	1 (US male)

While the overall percentage of US applicants remained close to 33%, the foreign applications rose to 68%, reflecting increases across all countries, including 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. Of the 24 graduates in 1987-88, no less than 19 embarked on such careers at Harvard, the University of Pennsylvania, and Boston University, to name a few. The remaining five have accepted or are considering non-university positions.

The Doctoral Program Committee, headed by Professor Arnold I. Barnett 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 May 27, 1988, 56 Alfred P. Sloan Fellows were awarded the degree of Master of Science in Management. The Class of 1988 re-elected 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 57th year.

Just prior to their graduation, the Sloan Fellows completed a three-week International Management Field Trip to Asia. They visited with leading government and industrial representatives in the People's Republic of China, Hong Kong and for the first time, Taiwan.

	<u>78-79</u>	<u>79-80</u>	<u>80-81</u>	<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>Industry</u>										
United States	31	30	31	30	28	26	30	26	31	33
International	10	11	13	15	13	15	13	12	14	12
<u>Government</u>										
United States	5	5	8	7	10	8	9	10	8	7
International	2	1	0	0	2	5	3	4	0	4
<u>Other</u>										
World Bank	0	0	0	0	0	0	0	0	0	0
Municipal Mgt.	0	0	0	0	0	0	0	1	1	0
Medical Mgt.	6	5	2	4	3	4	3	2	0	0
Church Mgt.	0	1	0	0	0	0	1	0	0	0
<u>University Mgt:</u>										
United States	0	2	1	1	1	1	1	1	1	0
International	0	1	1	0	0	0	0	0	0	0
	<u>54</u>	<u>56</u>	<u>56</u>	<u>55</u>	<u>55</u>	<u>56</u>	<u>57</u>	<u>54</u>	<u>55</u>	<u>56</u>

The demand for the program continues to be strong and the quality of the nominations is extremely high. One June 17, 1988, the Class of 1988-89 arrived; there are 54 participants in the 1988-89 program.

The Director of the Sloan Fellows Program, Alan F. White is an alumnus of the program (Class of 1971). Professor McKersie served as Chairman of the Faculty Program Committee.

Program for Senior Executives

The MIT Program for Senior Executives continues to evolve to keep abreast of a rapidly changing business environment, and during this past year gave increased emphasis to the global context of management, the importance of new technology as a basis of competition, and the need for rapid and effective organizational change. These ongoing program changes were facilitated by very close faculty coordination in both planning and execution. Class composition has been made more international to reflect this new

emphasis - over 40 percent of the participants are now from outside the U.S. The number of women in the program has also increased significantly; the spring 1988 class included five women, the largest number in the program's history. Demand for the limited number of spaces in each of the nine week fall and spring sessions continues to grow, with both sessions last year over subscribed.

The Director of the Program is Dr. Charles Grader, with Professor Henry Jacoby as Chairman of the Faculty Committee.

Greater Boston Executive Program

Continuing to serve as an important link between MIT and the Boston area community, the Greater Boston Executive Program enrolled 20 participants in the 1988 session held from January 29 through May 6.

The executives, 16 men and four women, 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 1988 Summer Session, School of Management faculty participated in nine Special Summer Programs.

Eight 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.

Three 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 Operations Management, administered by Dr. Harlan C. Meal; and a third in Corporate Strategy, coordinated by Professor Arnoldo C. Hax.

Three additional one-week programs were offered for the first time: 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 Professor John Sterman and David P. Kreutzer; and Emerging New Technologies for Decision Support: Models, Parallel Computing, and Knowledge-Based Systems was directed by Professor Jeremy Shapiro.

The remaining two programs had been offered in previous Summer Sessions: Corporate Planning and Control Systems, chaired jointly by Professor Paul Healy and Dr. Morris McInnes; and Operations Management in the Service Industries, directed by Professor Richard C. Larson of the Operations Research Center and by Professor Gabriel R. Bitran.

In addition to these programs offered as part of the Institute's Special Summer Programs, fourteen members of the faculty and staff directed or participated in two other sessions. In June, the Center for Information Systems Research offered its 13th annual summer meeting seminar on Current Issues in Managing Information Technology: Enabling Organizational Change, which was held at the Hyatt Regency in Cambridge; and MIT's Center for Transportation Studies sponsored a one-week seminar on Logistics Analysis for Carriers and Shippers which was held on campus.

Industrial Liaison Symposia and Seminars

During the Fall, School of Management faculty and staff also participated in several symposia, offered by the Industrial Liaison Program (ILP). In October at the Symposium on the emergence of the Pacific Rim: Technological and Managerial Implications for Business, which was held in Oakland, California, Professor Michael A. Cusumano spoke on Diversity and Innovation in Japanese Technology Management, and Dr. Mel Horwitch spoke on U.S. Technology Corporate Strategies for Meeting the Asian Challenge. In November at MIT, Professor J. D. Nyhart who chaired the Symposium on Computer Models and Modeling for Negotiation Management, spoke on New Developments in Negotiation Management, and Adjunct Professor Mary P. Rowe spoke about expert systems for complaint handling in corporate negotiations. Also participating in this symposium were Mr. Lance Antrim, who spoke on Experience in Computer Modeling in Negotiation and Mr. Peter Senge, who spoke on Accessible Simulation Modeling with Managers. In December, Professor Michael Scott Morton chaired a symposium at MIT on the Impact of Information Technology on Industries, Organizations, and Individuals. Also participating were Professor John D. C. Little, who spoke on Information Technology in Marketing; Professor John C. Henderson on the Impact of Strategy and Technology on Information Systems Design Team Performance; Professor Glen L. Urban on Educating Managers for the 21st Century; Professor Lotte L. Bailyn on Using Information Technology to Work from Office and Home: Possibilities and Problems; and Dr. John F. Rockart on Executive Support Systems - Changing the Planning and Control Process.

During the Spring, the ILP sponsored a seminar series of particular interest to the financial community. In March, Professor Kenneth A. Froot spoke on Exchange Rate Developments in the Short Run and the Long Run; in April, Professors N. Venkatraman and Stuart E. Madnick spoke on Electronic Filing of Individual Tax Returns: Implications for the Financial Services Industry and on Connectivity Among Information Systems respectively; and in May, Professor Donald R. Lessard discussed Corporate Finance and How Firms are Coping with the Shifting Dollar; Professor Thomas A. Poynter discussed the Role of Information Technology in Multinational Service Firms; Professor Michael A. Cusumano spoke on Software Development Management: The "Factory" Approach; Professor Peter J. Kempthorne discussed Modeling Stock Prices with Transactions Data; and Professor Chris F. Kemerer spoke on Models for Software Development Management. The seminars were held in Boston and in New York City.

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, concentrating on correlations among price movements and developing and testing the classical theory of storage.

Professor Pierre Regibeau has studied sellers' compatibility choice in industries in which buyers need to assemble several components to produce a working system. He has considered the determinants and effects of switching costs in such settings and studied the pricing and licensing behavior of multinational corporations.

Professor Nancy L. Rose, who was on leave as an Olin Fellow at the National Bureau of Economic Research and the University of Chicago, concentrates on the determinants and effects of government regulatory policies. She has studied the effects of airline deregulation on safety and the effects of firm size on technology adoption in the regulated electric utility industry.

Professor Julio J. Rotemberg, who was on sabbatical leave, has been working on several aspects of the interface between macroeconomics and imperfect markets. He has studied how 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, concentrating on adapters or converters and institutional structures for standard-setting. He has also studied the strategic consequences of vertical integration, collusive behavior, and price rigidity.

Professor Richard L. Schmalensee has studied changes over time in the relative profitability of large and small manufacturing firms. He has completed an invited survey of industrial organization and begun the study of implementable schemes of incentive regulation.

Professor Thomas M. Stoker has worked on the development of semi-parametric estimation techniques and their application to economic problems, concentrating on the estimation of average derivatives. He has also continued his research on consumer demand estimation.

Dean Lester C. Thurow while continuing his new position as Dean of MIT School of Management has published many papers including "Economic Paradigms and Slow American Productivity Growth" and has continued work on the productivity in the service sector.

Management Science

One of management science's great strengths is its diversity: drawing upon the field's disciplinary core of applied mathematics, computer science, optimization, and probability and statistics, a management scientist might work today on an issue in information technology, tomorrow an issue in manufacturing, marketing, transportation, or public policy.

This diversity permits management science to bridge numerous problem domains. At MIT, it has enabled management science faculty to contribute to issues that cut across the Management School, including such topics as statistical modeling in finance or behavioral aspects of group decision making; it has also enabled the Management Science Area to be a focal point for interactions between other parts of MIT and the Management School.

The interaction with the rest of MIT takes many forms. For example, management science faculty play lead roles in several interdisciplinary centers and laboratories at the Institute including the Artificial Intelligence Laboratory, the Center for Transportation Studies, and the Operations Research and the Statistics Centers. In addition, management science faculty have helped to spearhead the ambitious new joint Engineering School/Management School educational and research program entitled Leaders for Manufacturing. At a finer grain level, many management science faculty collaborate with colleagues elsewhere at MIT, particularly in the School of Engineering. For example, this past year Professor John Hauser of the Marketing Group published a paper on quality function deployment with Professor Donald Clausing of the Department of Electrical Engineering and Computer Science. Professor Peter Kempthorne of the Operations Research and Statistics group initiated research with Professor Thomas Sheridan from the Department of Mechanical Engineering on the development of filters for processing information from multiple sources, and Professor Stephen Graves continued his long-term collaboration with colleagues at Draper Laboratories on the design of assembly systems in manufacturing. These interactions have enriched the faculty's research and enabled them to expand the influence of their work.

The following discussion, organized around the area's four subgroups, provides a capsuled view of other aspects of the faculty's research.

Marketing. Marketing at MIT has always been noted for its emphasis on quantitative model building. Indeed, the marketing faculty have pioneered a field known as marketing science that brings quantitative modeling to bear upon a wide variety of issues in marketing. In keeping with this tradition, this past year Professor John Little's research focused on modeling approaches to the use of large databases of marketing information collected from checkout scanners at supermarkets. This research addresses such issues as the effects of advertising, coupons, and price promotions on consumer brand choices. Professors John Hauser and Alvin Silk were both on sabbatical at Harvard University; Professor Hauser has pursued new research on modeling issues related to quality function deployment and Professor Silk has been working on research in the area of measurement of marketing phenomenon. This Spring, Professor Wujin Chu, who also is an expert on quantitative approaches to marketing, joined the faculty with his recent doctorate earned at the Wharton School.

In other model-based work, Professor Glen Urban, in addition to his administrative responsibilities as one of the Deputy Deans of the school, has continued to conduct research on how lead users continued to collaborate with Professors Frank Kardes and Deborah Marlino on how consumers react to, categorize, and evaluate new atypical products. This last project entails an expanding commitment of the marketing group to behavioral issues in marketing. In other behaviorally oriented research, Professor Marlino has also been studying how memory affects the perception and learning of new information, and Professor Kardes has been examining a number of issues related to consumer judgment and inference processes.

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 challenges to management. The Management Information Systems Group addresses these issues by studying new information 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 of "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 of multiple "agents" has also been a major theme of Professor Thomas Malone's research. His research has focused on three issues (a) developing computer systems that help people work together in groups and organizations, (b) predicting and suggesting changes in human organizational structures that accompany the use of information technology, and (c) developing computer systems whose internal structure is based on insights gained from analyzing human organizations. In related research, Professor Stuart Madnick has begun to

analyze composite information systems that aim to coordinate applications requiring inter-organizational systems (e.g., between supplier and buyer) and intra-organizational systems. He has also continued to study database computers and has completed a book on software management. Professor John Henderson has begun a new study concerned with gaining value from information systems investments. He has also continued to study the value of strategic information systems planning, measurement and the effectiveness of information system's activities, and management of the design environment. Professor Chris Kemerer has pursued related research. He has examined the management of software engineering addressing such issues as cost estimation, measurement of productivity and quality, and computer-aided software engineering. Professor John Rockart has completed a textbook that brings together his years of research on executive support systems. He has also continued to investigate the issues of critical success factors and of management of data resources, and has pursued new work on the use of information technology to manage interdependent organizations of a firm.

Operations Management. Traditionally, the Operations Management Group has focused on modeling approaches to improving the design and management of operations in arenas as diverse as health care, manufacturing, logistics, and accounting and finance. This past year, the Group has placed considerable emphasis on manufacturing.

Professor Bitran has continued his long-term research aimed at understanding basic properties of a generic model, known as networks of queues, that arise in many manufacturing settings such as heat treatment, metalization of semiconductors, and environmental testing. He has also examined the impact of uncertainty in manufacturing systems, and issues of quality in service operations. Professor Fine has pursued, in part with colleagues from the School of Engineering, his research on quality management and process improvement and evaluation of manufacturing technologies. He has also begun work on the design-manufacturing interface and on information systems in manufacturing, as well as collaborated with Professor Stephen Graves on manufacturing computer components. Professor Graves has also studied a variety of issues in production planning, such as matching resources to work requirements, and initiated a new study of trading activities in banking. Professor Lode Li has initiated new work on the strategic role of inventory and on subcontracting, and continued to study the economic value of resource flexibility and manufacturing technology choice. In January, upon completing his doctoral program at Stanford University, Professor Lawrence Wein joined the faculty. He pursued research on networks of queues and on semiconductor wafer fabrication.

Operations Research and Statistics. The operations research and statistics group anchors 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 several 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, including oil and gas genesis and discovery and statistical and mathematical problems in resource estimation. Professor Peter Kempthorne has examined the influence of outlier data in regression analysis, as well as theoretical extensions of classical statistical decision theory and statistical modeling in finance. He has also begun 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, and computer guided diagnostics in statistics.

In the area of mathematical programming, Professor Robert Freund has worked on topics in fixed points, flexible manufacturing, and facility location. He has redirected most of his research, however, to studying new methods of linear programming that build upon the noted new algorithm developed by Narendra Karmarkar of AT&T Bell Laboratories. 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, on new algorithms for several fundamental core problems in network optimization. He has also worked on dynamic vehicle routing, optimization of algebraic systems, and new research in parallel and distributed computing. Professor Jeremy Shapiro, while on leave from MIT, has continued to work on a variety of applications of mathematical programming in such contexts as manufacturing, logistics planning, and raw material procurement. He has also examined methods of parallel computation for integer programming problems. Professor Thomas Magnanti has pursued his long-standing studies of network design in such problem contexts as production management and transportation planning. This year much of his efforts focused on issues that arise in the context of communication system design.

Personnel. After serving as Head of the Management Science Area for the past six years, Professor Magnanti has stepped down to assume co-directorship of the Institute's new Leaders for Manufacturing Program. Professor Bitran was appointed the new Area Head.

This past year several members of the Management Science Area received awards and honors. Professor Little was awarded the George E. Kimball Medal, the highest honor for professional service given by the Operation Research Society of America. Professor Hauser was named Editor of the journal Marketing Science. Professor Madnick was a recipient of an MIT graduate student council award for excellence in

teaching. Professor Magnanti became president of the Operations Research Society of America. Professor Marlino advised a student team that won the annual GM Marketing Competition. Professor Urban won the 1988 O'Dell Award for best paper published in the Journal of Marketing Research in 1983. Professor Wein received second prize in the 1988 George E. Nicholson Student Paper Competition held by the Operations Research Society of America. Professor Welsch was elected a full member of the International Statistics Institute.

Behavioral and Policy Sciences

The faculty in the Behavioral and Policy Sciences Area (BPS) bring a diverse set of social and behavioral science disciplines and methodologies to bear on a broad range of managerial and public policy issues. BPS is composed of faculty groups that focus on corporate strategy, human resources and industrial relations, technology and innovation, organization studies, international management, law, communications, and system dynamics. These subgroups are not only linked together for administrative purposes, but reflect our vision of the interdependence of these functional areas for addressing the critical challenges facing managers and policy makers today.

In summarizing our work of this past year, I will highlight that portion of our research that addresses some of the key challenges that we have chosen to give special emphasis in the the School's mission; namely, effective management of technology and social/organizational change in today's global competitive environment. But before summarizing the work of individual faculty, a historical sketch of the BPS heritage and unique perspective we bring to the topics of managing change, human resources, and technological innovation is in order.

BPS: Historical Background. In 1957 Professor Douglas McGregor, the Director of the Industrial Relations Section and forefather of our Organization Studies Group, gave his famous speech previewing Theory X and Theory Y, concepts that were to become the foundation for his class book, The Human Side of the Enterprise. McGregor's work sparked a generation of new thinking in participative management, organizational change and development, and the importance of human resources to organizational performance.

In the years that followed, the Organization Studies Group and the Industrial Relations Section took up these themes and together have redefined and broadened the fields of organizational change and human resources. The Organization Studies Group gave birth and nurtured the field of organizational development and planned change in the 1960s. Later, in the 1980s, faculty in the Industrial Relations Section laid the intellectual foundation for a new model of industrial relations that emphasizes employee participation and labor-management cooperation at the workplace and in strategic managerial decision-making and planning.

BPS faculty have also been on the forefront of establishing the professional field that is now known as the Management of Technological Innovation. As described in Edward Roberts' introduction to a book summarizing the evolution of this field, the management of technological innovation focuses on: the organization and direction of human and capital resources toward effectively (1) creating new knowledge; (2) generating technical ideas aimed at new and enhanced products, manufacturing processes, and services; (3) developing those ideas into working prototypes; and (4) transferring them into manufacturing, distribution, and use.

Our research program in this area started in 1962 with a major grant from the National Aeronautics and Space Administration. Over the course of 25 years, our faculty members have been doing important empirical research on such subjects as the management of technical professionals and the engineering and the R&D processes, the creation and management of new ventures, and the sources of innovation. Concepts and practices that are now well established in the profession, such as the technical gatekeepers and users as sources of new innovations, grew out of the work of our faculty.

Research Summary: 1987-88. This has been an extremely productive and rewarding year for BPS faculty. We published a number of new and exciting books and several faculty received awards from their peers in recognition of their contributions. In the following summary, special attention will be given to work that builds on and advances our heritage.

Organization Studies. As noted earlier, 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 and updated this tradition this past year with the publication of the second edition of his highly regarded book on Process Consultation. This work analyzes how consultants and managers use knowledge of group dynamics to facilitate the process of organizational change and development. We are pleased to report that Professor Schein will receive the American Psychological Association Perry L. Rohrer Award given in recognition of his outstanding work in the area of consulting psychology.

Professor Deborah Ancona has also been studying group processes in organizations with special emphasis on the performance of new product development teams. 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 also has examined 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. 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 Allen has continued his longstanding research on the careers of technical professionals and the performance of technical groups with support from the National Science Foundation. Currently Professor Allen is updating his classic work on the relationship between age of the group, external communications, and group performance to revisit his earlier findings that group performance tends to peak and then decay after about four years tenure.

Professor John Van Maanen published a new book Tales of the Field: On Writing Ethnography that explores his experiences with ethnographic methods over the course of his career. Professor Van Maanen has also continued working on studies of how emotions and feelings shape organizational cultures.

Professor Lotte Bailyn completed the empirical analysis for 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.

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.

As part of his work for the Management in the 1990s project, Professor John Carroll has completed work on three case studies of how managers' expectations for new information technologies influence 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. 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 are analyzing 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. Their current work focuses on the human resource policy tools used to reduce the labor force and to adjust to the new skill requirements. 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 Osterman's newly published book, Employment Futures: Reorganization, Dislocation, and Public Policy illustrates the links between the human resource policies of firms and public policy. He analyzes the dynamics of human resource practices within American firms and then builds a framework for analyzing how public policies of firms and public policy. He analyzes the dynamics of human resource practices within American firms and then builds a framework for analyzing how public policies can complement and diffuse innovation firm-level practices. Additional insights are drawn from a comparison of employment policies of Sweden, Germany, Japan, and the U.S. This work promises to play an important role in debates over the future of U.S. employment and human resource policies.

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 ombuds offices, Professor Rowe updated and published a paper on the legal issues associated with genetic testing of the workforce.

Professors Robert McKersie and Thomas Kochan extended their work on new models of labor-management relations by working with The Collective Bargaining Forum, a national group of corporate chief executives and union presidents. This group published a policy paper this year titled New Directions for Labor and Management in which they endorsed and encouraged the diffusion of many of the innovations in labor-management relations discussed in Professor McKersie and Kochan's recently published book, The Transformation of American Industrial Relations. The book will receive the Academy of Management's George Terry award for the best scholarly book on a management topic published this past year. Professor McKersie's leadership was further recognized by his academic and professional peers with his election as the President of the Industrial Relations Research Association.

Professor Phyllis Wallace continued her duties as this year's president of the Industrial Relations Research Association. In addition she completed her book manuscript in which she reports on the career and personal life experiences of a sample of Sloan School women and men graduates approximately five years into their careers.

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. As noted earlier, 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.

During this past year Professor Eric von Hippel's book The Sources of Innovation was published. This book summarizes Professor von Hippel's most recent work documenting the interdependence between users and developers of technologies. He also documents how one can predict the source of an innovation by analyzing who has the most to benefit from it. And in a paper published jointly with Professor Glen Urban, von Hippel extended the concept of "lead users" as sources of new product ideas.

Professor Michael Rappa joined our faculty this year and 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 mode.

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.

Strategy and Policy. While almost 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 fourth 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 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). Several working papers have been drafted in anticipation of combining them into a book manuscript in the upcoming year.

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. This past year he published a paper on planning systems and is now initiating a major project with several colleagues to examine the strategic value of using information technology. IBM is funding this project.

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.

Professor Eleanor Westney is an organizational sociologist with special expertise and interest in Japan. This past year she published a new book titled Imitation and Innovation in which she analyzed how western organizational patterns and concepts were adopted and adapted in Japan during the Meiji period. Professor Westney also continues her comparative analysis of engineering careers and organizational structures in American and Japanese computer firms. One of her most interesting findings in this work is that in Japanese firms ideas, technology development, and new products tend to transfer through the transfer of project leaders from R&D to manufacturing. She suggests that this is a major reason why Japanese firms seem to be highly efficient in process innovation, technology transfer, and new product development. Professor Westney's work represents another example of conceptual linkages we are exploring between technology, human resource practices, and organizational design and change.

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 summarized much of his current work on this topic in a publication of 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.

Senior Lecturer Jeffrey Meldman continued his work on legal aspects of software development and artificial intelligence.

System Dynamics. The field of System Dynamics was founded at MIT by Professor Jay Forrester. This past year Professor Forrester continued drafting chapters for a forthcoming book on his national economic model.

Professor John Sterman and Research Associate Peter Senge have also continued developing computerized case studies which can be used as "learning laboratories" in both action-oriented research and in teaching. A prototype of the People's Express case will be used as part of our orientation process for incoming Master's students this fall.

Communication. Senior Lecturer JoAnne Yates published several papers in her ongoing work on the evolution of communications technologies in industry. As part of her interest in this topic she is preparing a chapter for the Management in the 1990s research volume on the historical evolution of information technologies and their impacts on communications patterns and structures.

John D. C. Little: A Word of Thanks

Finally, this year marks the transition in the leadership of the BPS Area. We gratefully acknowledge the contributions that Professor John D. C. Little made as the head of our area from its inception in 1982 through this year. Professor Little will now return to research and teaching in the Marketing Group. We wish him well. During this past year Professor Little put his exposure to the behavioral sciences to work in a paper he published that reported the results of an experiment in voting patterns given various governing rules. We are also happy to report that Professor Little was awarded the George E. Kimball Medal of the Operations Research Society for his distinguished service to the society and the profession.

AFFIRMATIVE ACTION

The School modified its strategy in the area of Affirmative Action this past year. Three senior faculty, Professors Gordon Kaufman, Ernst Berndt, and Lotte Bailyn were asked to investigate the issues faced by men and women at Sloan and to begin to develop a strategy that would result in bringing qualified women and minorities in all ranks to the School. The progress in hiring underrepresented minorities is essential not only to meet moral and legal imperatives, but also because an increased diversity among ourselves is necessary for us to adequately prepare our students for the management issues they will face in the future.

As the three faculty researched issues, they also pursued their colleagues in order to identify minorities for our open faculty positions. Their efforts resulted in the appointment of one black visiting faculty member as well as two female faculty.

We have continued our serious search process and have this year initiated a mid-year review with search chairpersons in order to determine if the efforts outlined in the original search plans have yielded the anticipated number of minority candidates. In cases where this has not been as successful as we hoped, the Dean's Office has offered assistance and advice to help the search along in its final stages.

The School continues to raise funds from corporate sponsors to support minority candidates in our degree programs. We are also continuing our efforts to increase contributions to the Phyllis A. Wallace Doctoral Fellows Fund and Visiting Scholars Fund to provide support to black visitors at the School.

Finally, as funding levels from Central Institute sources have diminished, the Sloan School has agreed to fund a number of incoming as well as returning minority masters degree candidates next year from our own unrestricted gifts. It is anticipated that if the number of incoming minority students accept our offers as expected, total funding for this program will approximate \$140,000.

EXTERNAL RELATIONS

During the transition for the new administration, our Resource Development Office yielded over \$13 million in expendable revenue in FY88 up from \$1.2 million in FY87 and over \$3 million in endowment for the School compared with \$2.5 million in FY87. Cash received for FY88 reached a total of over \$4.5 million dollars as compared with over \$3.6 million in FY87. The school also generated in FY88, \$2,343,455 in pledges most of which is to be paid off over the next five years. Though the total percentage of Sloan alumni donors decreased from 9.5 percent in FY87 to 8.3 percent in FY88, the total dollars from alumni donors increased from nearly \$283,000 in FY87 to over \$325,000 in FY88 along with another \$575,117 from alumni associated family trusts.

Notable among the gifts were the establishment of the Mitsubishi Bank Chair in finance with a FY88 gift of \$1.5 million and the payment of \$500,000 on a \$1.5 million pledge by Dai-Ichi Kangyo Bank to set up an endowed professorship in management. In addition to these two chairs, a number of donors have committed to significant gifts toward the establishment of a Howard Johnson Chair honoring the former Dean of the Sloan School. Among these donors, the Grayce B. Kerr Fund (Breene Kerr 51GY) pledged \$400,000, Champion International Corporation pledged \$400,000; Champion International Corporation pledged \$300,000; DuPont De Nemours & Company pledged \$300,000; Morgan Guaranty Trust Company, New York pledged \$150,000 and Federated Department Stores Inc. pledged \$125,000.

Other notable gifts were the pledge payment of Patrick McGovern (59LI) for \$300,088 toward the Patrick McGovern Chair in the area of management and information systems, the Coopers & Lybrand gift of \$150,000 towards investigating the impact of advanced information technology on public accounting, and a gift of \$100,000 from CIGNA Corporation for management theory and advanced technology. Ray and Maria Stata Family Charitable Fund (Ray Stata 57EE) continues to support System Dynamics with a total of \$81,117. Digital Equipment Corporation provided a gift of over \$50,000 to support System Dynamics.

Other significant alumni gifts were a pledge of \$300,000 from DuWayne Peterson (55MG) to establish the DuWayne Peterson doctoral fellowship in informational technology and an unrestricted gift of \$125,000 from the Loomis Foundation (Wesley Loomis 35MG). Another notable gift of \$125,000, from Lehigh Investment Trust, was arranged by Zenon Zannetos' (GM55) widow, Clotilde. This gift for fellowships was designated for the Zenon S. Zannetos Endowment Fund.

Over the coming years, we intend to increase the level of participation and the amount of donations from both our alumni and non-alumni donors. With a new mission statement and with an increased emphasis on involving alumni and friends in our efforts to take the School to the cutting edge of the future management education, we look forward to a significant increase in revenue to the Sloan School over and beyond the Campaign for the Future.

STAFF CHANGES, PROMOTIONS, AND VISITORS

The 1987-88 academic year began with the appointment of two new Deputy Deans. Professor Arnaldo C. Hax, Alfred P. Sloan Professor of Management, joined the faculty in 1972. Professor Hax is both an excellent teacher, who communicates enthusiasm regarding his subject matter, as well as researcher well known for his work on hierarchical production planning systems. His interests cover the areas of industrial engineering, operations research, operations management, strategic management and business policy.

Professor Glen L. Urban was also appointed Deputy Dean and was appointed to one of the Schools new chairs through a donation from the Dai-Ichi Kangyo Bank. Professor Urban joined the faculty in 1966; he has spent his career in building management science models to improve marketing problems. Professor Urban is one of the world's leading authorities in the field of new product design and development. He is an inspired teacher as well as a prolific author who has published many fast-breaking books on marketing science.

Three other new chair appointments were made during the year. Professor Kenneth A. Froot, who joined the faculty in 1986, has conducted research in the area of International Finance.

Professor Robert S. Pindyck was named to a new chair, the Mitsubishi Bank Professorship in Finance, established by the generous gift of the Mitsubishi Bank. Professor Pindyck joined the MIT faculty in 1971 and has concentrated his research in the economics of natural resources, the behavior of energy markets, the design of economic policy, and econometric modeling and forecasting.

Professor Abraham J. Siegel was appointed to a new chair, the Howard W. Johnson Professor of Management, established through the contributions of Champion International, Dupont DeNemours, Federated Department Stores, John Hancock Life, Morgan Guarantee Bank and Grace B. Kerr Fund, Inc. Professor Siegel joined the MIT faculty in 1954, has held appointments in the Department of Economics as well as the Sloan School, and served as Dean from 1980-1987. Professor Siegel's research interests have largely been in the area of labor management relations, organizational development, and the management of human resources.

Three of the faculty were promoted to the rank of Professor this year. Professor Arnold I. Barnett received a Ph.D. degree in Applied Mathematics from MIT in 1973. He joined the Operations Research faculty in 1975 and has concentrated his research in the areas of ill-structured public sector management problems which he has subjected to careful analysis using probabilistic modeling techniques.

Professor Stephen C. Graves was granted a Ph.D. degree in Management in 1977 from the University of Rochester. Professor Graves has been a part of the Sloan faculty in the Operations Management Group since 1977. His major research interests have been in the area of automatic warehousing systems, assembly system design, production and inventory control, multi-stage inventory systems, and hierarchal production planning and scheduling.

Professor James B. Orlin joined the Sloan School faculty in 1979 in the Operations Research Group. Professor Orlin received a Ph.D. degree in Management in 1981 from Stanford University. Professor Orlin received a Ph.D. degree in Management in 1981 from Stanford University. Professor Orlin's major research area is combinatorial optimization; he is credited with having pioneered the study of dynamic/periodic optimization problems.

Four of the faculty were promoted from Assistant to Associate Professor. Robert M. Freund received a Ph.D. degree in Operations Research in 1980 from Stanford University. He joined the Sloan faculty in 1983 and has conducted research in the area of fixed point theory; in particular, he has investigated the connection between combinatorial theorems and topologically-based fixed point algorithms.

Professor Chi-Fu Huang received a Ph.D. degree in Management in 1983 from Stanford University. Professor Huang has been a part of the Economics Group since 1983 and has conducted research in the area of financial theory, including dynamic general equilibrium theory, intertemporal utility theory, auction theory, and the theory of optimal consumption and portfolio decisions.

Professor Judith A. Lachman became a member of the Sloan faculty in 1986. Professor Lachman earned a J.D. degree from Yale University in 1982. In her research, she has employed economic models and thought to analyze and explicate doctrinal issues in law.

Professor Robert J. Thomas received a Ph.D. degree in Management in 1981 from Northwestern University. He has been a part of the Organizational Studies faculty since 1986 and has pursued research interests in organizational change and design with emphasis on the process and politics of technological change.

JoAnne Yates was promoted from Lecturer to Senior Lecturer. Dr. Yates became a member of the MIT faculty in 1980. Dr. Yates earned a Ph.D. degree in English in 1980. Dr. Yates earned a Ph.D. degree in English in 1980 from the University of North Carolina and has pursued research on the history of internal communication in the American firm.

Three visiting faculty from the prior academic year became part of the faculty this year. Professor Paul Osterman joined the Labor Relations group as Associate Professor with tenure. He received a Ph.D. degree in 1976 in Economics and in Urban Planning from MIT. Professor Peter Kempthorne joined the faculty as an Associate Professor. Professor Kempthorne received a Ph.D. degree from the University of California in 1982 in statistics. Garth Saloner, Associate Professor of Applied Economics, also joined the Sloan faculty. Professor Saloner has a joint appointment with the Economics Department. He received a Ph.D. degree in 1982 in Economics from Stanford University.

Six new assistant professors joined the Sloan faculty. Wujin Chu, Assistant Professor of Marketing, received a Ph.D. in Marketing from the University of Pennsylvania in 1986. Chris F. Kemerer, Assistant Professor of Management Science, received a Ph.D. from Carnegie-Mellon in 1987 in Information Systems. Michael A. Rappa, Assistant Professor of Management, received a Ph.D. degree in 1987 from the University of Minnesota in Strategic Management. Pierre Regibeau, Assistant Professor of Management, received a degree of Licence in 1979 from the University DeLiege in Belgium. David Scharfstein, Assistant Professor of Management, received a Ph.D. degree from MIT in Economics in 1986. Lawrence M. Wein, Assistant Professor of Management Science, received a Ph.D. degree in 1987 from Stanford University in Operations Research.

The School welcomed a number of four visiting faculty this year. Professor Peter Brownell from Macquarie University in Australia taught Managerial Accounting and Control; Samprit Chatterjee from New York University taught and performed research in conjunction with the Statistics Group; Robert A. Taggart from Boston University taught Financial Theory; Thomas Vargish from the University of Maryland taught in the Senior Executive Program.

Four associate professors visited the School: Per Olov Lindberg from the Royal Institute of Technology in Stockholm taught the Introduction to Management Science; Rajnish Mehra from the University of California taught Finance Theory; Thomas Poynter from the University of Western Ontario taught International Dimensions of Management, Strategy in a Global Context, and Assessing Foreign Business Environments; Thomas Selling from the Amos Tuck School of Business Administration taught Accounting and Finance.

Two assistant professors visited this year: Antonio S. Mello from London Business School taught Finance for International Managers and a Special Seminar in Management; Y. Richard Wang from the University of Arizona taught Management Information Technology.

Faculty on professional leave included John J. Donovan, Associate Professor of Management Science; Chi-fu Huang, Associate Professor of Finance; Nancy L. Rose, Assistant Professor of Applied Economics; Jeremy F. Shapiro, Professor of Operations Research and Management; M. Anthony Wong, Associate Professor of Management and John R. Hauser, Professor of Management Science.

Faculty who returned from leave included Lotte Bailyn, Professor of Organizational Psychology and Management; Arnolde C. Hax, Alfred P. Sloan Professor of Management; John E. Parsons, Assistant Professor of Finance; Thomas M. Stoker, Associate Professor of Applied Economics; Glen L. Urban, Dai-Ichi Kangyo Bank Professor of Management Science; and Eleanor D. Westney, Mitsubishi Career Development Associate Professor in International Management.

Administrative staff promotions included Jean F. Anderson who was promoted from Administrative Assistant on the support staff to Administrative Assistant, Staff; Donna M. Behmer was promoted from Assistant Dean for Administration to Associate Dean of Finance and Administration, Neil G. Buckley who was promoted from Administrative Coordinator to Administrative Manager; Judith E. Mason was promoted from Administrative Assistant on the support staff to Area Coordinator.

Administrative staff who joined the School included Olimpia E. Caceres, Systems Programmer II; Anne L. Drazen, Director of Information Systems; and Maria Lucas, Administrative Coordinator, Staff.

Changes in designation for the administrative staff included Paula Budlong Cronin, Director of Public Information and Editor, MIT management; and Hillary H. DeBaun, Undergraduate Program Administrator.

The school welcomed one research scientist, Keh-Chiang Yu.

One faculty member retired this year, Franco Modigliani, Institute Professor of Finance and Economics.

A number of individuals departed the Sloan School this year including Professor Alvin J. Silk; Associate Professors Katharine G. Abraham, Terry A. Marsh and M. Anthony Wong; Assistant Professor Pierre Regibeau; Senior lecturers Stan Finkelstein and Michael Hagerty; Lecturers Albert A. Marcotte, Sandra Nickel, Maryann Piotrowski; Administrative Staff Neil G. Buckley, Wanda Osborn, and Miriam Sherburne; Research Staff David DeLong and Sarah A. Finegan. All of these individuals made fine contributions to the School.

Senior Lecturers and Lecturers newly appointed at the School included: David Breakstone, who taught Communication for Managers; Arline Golden who taught Communication for Managers; Michael Hagerty, who taught Introduction to Marketing; Mel Horwitch, who taught Strategic Management; Julian Kielson who taught Operations Research; Wesley Liebttag, who taught a Special Seminar in Industrial Relations; Donald Rappaport taught Introduction to Financial Accounting and James Womack who taught International Technology Transfer.

The School also welcomed Visiting Scientists Ravindra K. Ahuja who worked with Professor James Orlin. Ravindra Ahuja was Assistant Professor in the prior year; Gary Perlman, who worked with Professor Thomas Magnanti; Armin Claus, who worked with Professor Arnold Barnett; Vijay Gurboxani, who worked with Professor Thomas Malone.

A number of faculty were on sabbatical leave all or part of the year: Stephen C. Graves, Professor of Management Science, was on leave for the Spring term; faculty on leave for the year included Robert C. Merton, J. C. Penney Professor of Management; Stewart C. Myers, Gordon Y Billard Professor of Finance; Julio J. Rotemberg, Associate Professor of Applied Economics; and Alvin J. Silk, Erwin H. Schell Professor of Management.

LESTER C. THUROW

SCHOOL OF SCIENCE

During the past year, the Department of Applied Biological Sciences was phased out and the faculty members of that department were relocated in other academic units. This action was taken only after careful consideration by the Dean of Science and with the concurrence of the Provost and the President. This department has been in existence, under different titles, for 43 years, and during that time many important and significant contributions have been made by distinguished faculty members in several areas of research and education. The department was organized in 1945 when the then existing Department of Biology and Biological Engineering was divided into two departments and Professor William L. Campbell became the first Head of the new Department of Food Technology. Professor Bernard E. Proctor became Head in 1951 and in 1960 Professor Nevin Scrimshaw, a distinguished nutritional scientist, was recruited as the new Head with the mandate to establish nutrition as a new focus in the Department. At that time, the name was changed to the Department of Nutrition, Food Science and Technology to recognize the new initiative in nutrition. The name was shortened a few years later to Nutrition and Food Science. In 1979, Professor Gerald Wogan became the Head of the Department and in the next few years the focus of the department gradually shifted from nutrition and food science to other disciplines such as toxicology, biochemical engineering, industrial microbiology, and other areas of biotechnology. In 1984 the name of the department was changed, once more, to the Department of Applied Biological Sciences to reflect the department's developing interests in the broad areas of applied biology.

The closing of the Department of Applied Biological Sciences does not mean that MIT is any less interested in applied biology. Biotechnology is an interdisciplinary field with intellectual ties to areas of fundamental research such as molecular genetics and biochemistry as well as to chemical engineering. The relocation of Applied Biological Sciences faculty members in other academic departments should promote intellectual interactions with colleagues having similar and complementary interests and is, therefore, expected to strengthen the efforts in biotechnology at MIT. The faculty members associated with the toxicology program will hold appointments in the Whitaker College of Health Sciences; faculty in the area of biochemistry will hold appointments in the Department of Chemistry, and faculty in the biotechnology area will hold appointments in the Departments of Biology, Chemistry, and Chemical Engineering.

With the help and cooperation of Prof. Frank Perkins, Dean of the Graduate School and Prof. Steven Tannenbaum, Graduate Officer of Applied Biological Sciences, a plan has been developed to encourage and permit graduate students who were admitted to degree programs in the Department of Applied Biological Sciences to finish their programs in a timely fashion. Similarly, a plan is in place to permit undergraduate students who have chosen the 7B program, a life sciences undergraduate program with subject options in Applied Biological Sciences, to complete the requirements for a B.S. in this program.

The Dean of Science wishes to thank all of those individuals who have been so helpful and cooperative in the generation and the implementation of these plans.

EDUCATION

The report of the School of Science education committee, mentioned in last year's report, raised several questions in education that obviously needed addressing by a more broadly-based campus group. These questions are primarily concerned with (a) the science and mathematics "core requirements" (taken by students usually during the first year), (b) the nature and extent of laboratory requirements in science, (c) the advisability and feasibility of adding a life sciences requirement to the "core", and (d) the role of science distribution subjects. All of these issues are interrelated and, because of their campus-wide impact, the offices of the Deans of Engineering, Science, and Undergraduate Education have jointly sponsored the formation of a new "Working Group" to consider these questions. This group is composed of faculty members from the Schools of Science, Engineering, and Humanities and Social Sciences as well as student members. The Working Group, under the joint leadership of Professor Wormley of the Department of Mechanical Engineering and Professor Silbey of the Department of Chemistry, has been meeting regularly during the spring term of the 1987-88 school year and the expectation is that the meetings will continue during the fall term of the 1988-89 year.

STAFF CHANGES

On June 30, 1988, Professor Jerome I. Friedman stepped down as Head of the Physics Department after having served for a five-year term. Professor Friedman has been an effective spokesman for physics at MIT in the past five years. I have grown to appreciate his commitment to excellence and his compassionate nature during his tenure on Science Council. He has my best wishes for a continued outstanding career at MIT as he returns to full-time teaching and research.

Professor Friedman's successor as Head of the Physics Department is Dr. Robert J. Birgeneau, Cecil and Ida Green Professor of Physics. Professor Birgeneau is a distinguished scientist and an international leader in the field of condensed matter physics. He has been a member of the faculty at MIT since 1975. I welcome him to Science Council and look forward with enthusiasm to working with him.

After eight years of service as Head of the Department of Earth, Atmospheric, and Planetary Sciences, Professor William F. Brace relinquished this post on June 30, 1988, and returned to the department to devote full time to research and teaching. Professor Brace has been a dedicated and effective member of Science Council. I am sure that I shall take advantage of his continued presence at MIT by seeking his advice many times in the future.

Professor Thomas H. Jordan will replace Professor Brace as Head of the Department of Earth, Atmospheric, and Planetary Sciences. Professor Jordan is a geophysicist known internationally for his contributions to the theory of plate tectonics and to the understanding of the structure of Earth's interior. He joined the faculty at MIT in 1984 and has rapidly established himself as a leader in his field and in the department. I am enthusiastic about working with him and interacting with him on Science Council.

SCIENCE COMPLEX

The plans for the establishment of a science complex were summarized in last year's report. These plans include the construction of a new building to house a portion of the Department of Biology and the renovation of the Dorrance Building (Building 16) to accommodate part of the Physics Department. In the past year, an agreement has been reached with the Howard Hughes Medical Institute (HHMI) to establish a unit of the HHMI at MIT which will include up to eight faculty members, who will hold joint appointments with the Department of Biology. The HHMI has also agreed to supply approximately one-third of the funds needed for the construction of the new biology building. Plans for this new building are currently being generated.

During the past year, the Green Center for Physics was established at MIT. This center was named for Cecil and Ida Green, who have been so generous with their time and resources in the support of MIT over the past two decades. The establishment of the Green Center coincided with a generous gift from Cecil Green which will be used to renovate the Dorrance Building for the Physics Department.

AFFIRMATIVE ACTION

There were two appointments of females and underrepresented minorities in the School during this year. The Physics Department appointed Dr. Katherine Freese as Assistant Professor this past year. Dr. Stella Ashford has accepted an offer from the Department of Mathematics as Visiting Associate Professor for the 1988-1989 academic year. In addition, an offer was made for a faculty position to a female (Physics), who declined the offer.

Professor Leigh Royden of the Department of Earth, Atmospheric and Planetary Sciences was promoted to Associate Professor and Professor Sylvia Ceyer of the Department of Chemistry was granted tenure.

The MIT Minority Summer Science Research Program, initiated in the summer of 1986, is continuing to expand and to be very successful in providing minority undergraduate students the opportunity to spend the summer at MIT working in the research laboratories of selected faculty members in the School of Science. For the summer of 1988, the sixteen students were selected for this program from applicants received from a nationwide solicitation. The program is designed to encourage minority students to apply to graduate schools in mathematics and the physical and biological sciences. Many people are to be thanked for the success of the program: department heads, participating faculty, graduate students, postdoctoral trainees, and especially Dean John Turner, Associate Dean of the Graduate School, who has provided the leadership for this program. Thanks are also expressed to the National Science Foundation, the Carnegie Corporation, Proctor and Gamble, Honeywell, Inc., Pfizer, Inc., and the Dow Chemical company for their generous financial support for this program.

RESEARCH VOLUME

The FY'88 volume of research was approximately \$95 million. This represents a 7 percent increase over the FY '87 total of 89 million.

ACADEMIC PROGRAMS

There were 766 undergraduates in the School of Science during the past academic year, a slight decrease from the previous year. The number of minority students at the undergraduate level changed as follows:

Blacks:	increased from 14 to 16 (14%)
Hispanics:	decreased from 19 to 16 (-15%)
Native Americans:	decreased from 1 to 0 (-100%)
Asian Americans:	increased from 121 to 133 (+10%)

The female undergraduate population increased by 14.5%. Twenty-three percent of the Institute's upperclass undergraduates were enrolled in the School of Science.

Graduate enrollments in science decreased from 1,115 in the 1986-1987 academic year to 1,109 in the 1987-1988 academic year. The total enrollment represents 21 percent of the graduate population at MIT. The number of minority students at the graduate level changed as follows:

Blacks:	decreased from 19 to 17 (-10%)
Hispanics:	No change
Native Americans:	No change
Asian Americans:	increased from 4 to 5 (25%)

The number of female graduate students decreased slightly.

There were 273 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.

HONORS AND AWARDS

In the Department of Applied Biological Sciences, Professor Arnold Demain was awarded the following honors: elected to Fellowship in the Institute for Biotechnological Studies (U.K.); awarded the Gregor Mendel Award (Czechoslovakia); awarded the Kitasato Institute Medal in Microbial Chemistry (Japan). Professor Robert Langer was elected to serve as Chairman of the 1988 Gordon Research Conference on Drug Carriers in Biology and Medicine. He gave the first Presidential Lecture to the International Controlled Release Society in Basel, Switzerland, and the Robert Rushner Lecture at the University of Washington - Seattle. Professor Helmut Zarbl was awarded the Robert A. Swanson Career Development Professorship.

The Nobel Prize in Medicine was awarded to Professor Susumu Tonegawa of the Biology Department for his research on the rearrangement of genes in cells of the immune system. In addition, Professor Tonegawa was a co-recipient of the 1987 Albert Lasker Medical Research Award, which is ranked by this country's medical community to be second only to the Nobel Prize.

Professor Daniel Kemp of the Chemistry Department was the recipient of the Science Council Prize for Excellence in Undergraduate Teaching. The prize is given by Science Council to recognize outstanding instructional performance.

This past year Professor Isadore Singer of the Department of Mathematics was named to the distinguished rank of Institute Professor. Professor Singer is one of the most important figures in the mathematical world today.

I am pleased to report that Professor Jerome Friedman of the Department of Physics has been selected as the first holder of the William A. Coolidge Professorship in recognition of his important contributions to the field of high energy physics and to teaching.

GENE M. BROWN

Department of Biology

EDUCATIONAL ACTIVITIES

Undergraduate Program

In the past year, the maximum number of undergraduates registered as Life Sciences majors was 278. Of these, 87 received the degree of Bachelor of Sciences in Life Sciences: 62 in the regular Course VII Program, 18 in the VII-A Program, and seven in the VII-B Program.

The recipient of the John L. Asinari Award for outstanding research by undergraduates in Life Sciences for 1987-1988 was Brian C. Schaefer, a junior, working in the laboratory of Professor Renee Fitts in the Department of Applied Biological Sciences.

We have added two new subjects to the undergraduate curriculum, to be taught for the first time during the 1988-89 school year. Subject 7.00 AIDS - Scientific and Human Challenges will be offered as a six unit Context subject to provide a multidisciplinary scholarly overview of the basic science and scientific puzzles illuminated by AIDS, and to engage students in the extraordinary social and political issues provoked by this disease. Subject 7.041 Experimental *Drosophila* Molecular Genetics will complement our existing project laboratories in microbiology, yeast, and mammalian cells (7.031, 7.15, 7.16). Given the now widespread use of *Drosophila* as a model system to study questions of gene control, development, and neurobiology, we feel strongly that students should have an opportunity for exposure to this field at an experimental level.

Graduate Program

During the period from July 1, 1987 to June 30, 1988, 21 Ph.D. degrees and two Master's degrees were awarded in the Department; three 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 1987-1988 was 170, with another 19 in the Joint Program. The entering class in 1987, including three in the Joint Program, was 43. The class arriving in September, 1988 will be 32, including three WHOI students.

A new graduate seminar 7.67J/9.322J Genetic Neurobiology will be offered for the first time in the spring semester 1989 which will further strengthen our growing program in neurobiology.

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 publication, *Biology Research Summaries*, available in the Biology Headquarters Office (56-511). Plans for the new Biology building which will provide modern research space for about half of the Department are being developed. The Howard Hughes Medical Institute has contributed funds toward the construction of this building, and has selected three faculty members to be Hughes Investigators at MIT (see below).

PERSONNEL

During the past year, Drs. Steven J. Burden, H. Earl Ruley, and Richard A. Young were promoted to Associate Professor, effective July 1, 1988.

Dr. Alan D. Grossman joined our faculty as an Assistant Professor June 1, 1988. Dr. Grossman received the Bachelor's Degree in Biochemistry in 1979 from Brown University and the Ph.D. in Molecular Biology from the University of Wisconsin, Madison, in 1984. From 1985 until he joined the Department, he was a Postdoctoral Fellow at Harvard University. Dr. Grossman's research interests focus on the extracellular regulation of sporulation in *Bacillus subtilis*.

Dr. Harald von Boehmer will join the Department and the Center for Cancer Research in April, 1989 as Professor of Biology. Dr. von Boehmer received the M.D. Degree from the University of Munich in 1968 and the Ph.D. in 1974 from Melbourne University. He has been a Member of the Basel Institute for Immunology in Basel, Switzerland, since 1974, following a postdoctoral fellowship at the Max Planck Institute for Biochemistry and an internship at the University of Munich. In addition, he has been an Adjunct Professor in the Department of Pathology, University of Florida, since 1982. Dr. von Boehmer is recognized as a world leader in cellular immunology, in particular for his work in the field of T cell recognition and development.

Four faculty members from the Department of Applied Biological Sciences, Drs. Marie Chow, Arnold Demain, Kim Lewis, and Anthony Sinskey, have been welcomed into the Department.

Three faculty members, Professors H. Robert Horvitz, Richard O. Hynes, and Susumu Tonegawa, have been appointed Hughes Investigators.

Professors John M. Buchanan and Jerome Y. Lettvin retired from the Institute June 30, 1988 after 35 and 37 years of service, respectively. We will miss them and wish them well in their future careers.

Honors and Awards to the Faculty

It is a pleasure to report the following honors and awards received by various faculty members in the past year:

Dr. David Baltimore has been elected a Fellow of the Institute of Medicine and was the recipient of the 1987 Rabbi Shai Shacknai Memorial Prize in Immunology and Cancer Research.

Dr. Brent Cochran was selected as the first holder of the Pfizer Career Development Professorship.

Dr. Maurice Fox was elected to the National Academy of Sciences.

Dr. H. Robert Horvitz received the USX Foundation Award in Molecular Biology from the National Academy of Sciences for his "signal contributions to the genetic analysis of the development of cell lineages in the nematode *C. elegans*."

Dr. David Housman received a National Institutes of Health Merit Award and has been elected a Fellow of the American Association for the Advancement of Science.

Dr. Arthur Lander has been named the Edward J. Poitras Assistant Professor of Human Biology and Experimental Medicine.

Drs. Terry Orr-Weaver and Hermann Steller were the recipients of Searle Scholar Awards for 1988.

Dr. Donald Rio received a Presidential Young Investigator Award.

Drs. Paul Schimmel and Alexander Varshavsky were elected to the American Academy of Arts and Sciences.

Dr. Frank Solomon received the Graduate Teaching Award for the fourth time.

Dr. Phillip A. Sharp was named the second holder of the John D. and Catherine T. MacArthur Professorship.

Last but far from least, Dr. Susumu Tonegawa received the 1987 Albert E. Lasker Medical Research Award and the 1987 Nobel Prize in Medicine or Physiology for his work "revolutionizing the understanding of the human immune system."

MAURICE S. FOX

RICHARD O. HYNES

ACTIVITIES OF THE DEPARTMENT

A Strategic Planning Committee has been appointed by the Department Head which includes Professors Rick L. Danheiser, Stephen J. Lippard, Robert J. Silbey, and JoAnne Stubbe, and the Department's Administrative Officer, Mr. Marc Jones. This new committee is charged with helping to formulate Departmental goals for the next five years, and will receive input from all sectors of the Department.

A representative group of undergraduate and graduate students was appointed to serve on The Chairman's Council, a new organization designed to advise the Department Head on current problems and issues of relevance to the Chemistry student body. Some topics of discussion have been: creation of an undergraduate lounge, selection of research advisors by first-year graduate students, teacher evaluations for graduate courses, and improvement of the seminar system.

The MIT Chemistry High School Outreach Program was developed in the Fall of 1987 by the Department Head and two Chemistry graduate students from the group of Professor Rick L. Danheiser. Graduate students visit public school chemistry classrooms and present lectures and demonstrations to illustrate chemical research process and to bring the excitement of chemistry to students of local public schools. During the Spring 1988 semester, the program was presented to approximately 500 students in chemistry classes at nine Boston Area high schools. The program has met with considerable success in its first year, and more lectures and demonstrations are planned for the Fall of 1988. Presentations suitable for elementary grade levels are also being planned. It is hoped that this outreach program will help the Department and MIT to improve the public image of chemistry and encourage young people to pursue careers in the field.

Chemformation, a weekly Departmental newsletter, was launched and delivered to the MIT Chemistry community and a number of outside recipients throughout the 1987-88 academic year. Among its other services, this newsletter provides job listings for graduate students and better coordination of the Departmental seminar calendar.

A two-day symposium entitled "Future Chemistry: Recent Achievements and New Opportunities" was presented on November 13 and 14, 1987 by the Department of Chemistry and the MIT Industrial Liaison Program, and chaired by the Department Head, Professor Mark S. Wrighton. The symposium consisted of three sessions, each session consisting of three presentations followed by a panel discussion. The first session was on the topic of chemical synthesis, the second was on materials chemistry, and the third concentrated on interface science. Distinguished speakers were invited from industry, and presenters from the Department included Provost and Professor John M. Deutch, and Professors Glenn A. Berchtold, Sylvia T. Ceyer, Rick L. Danheiser, Richard R. Schrock, Dietmar Seyferth, K. Barry Sharpless, Robert J. Silbey, and John S. Waugh. Professor Gene M. Brown, Dean of the School of Science, served as a panel member. The audience included representatives from many of the companies supporting MIT's Industrial Liaison Program, and those involved in the direct support of the Chemistry Department.

A day-long symposium and dinner were held on November 16, 1987 to honor Professor James L. Kinsey, a former Department Head and Professor of Chemistry at MIT until his appointment in January 1988 as Dean of Natural Sciences at his *alma mater*, Rice University. Professor Robert J. Silbey served as Master of Ceremonies, and speakers included MIT Provost John Deutch and Professors Robert W. Field and Sylvia T. Ceyer.

The George H. Büchi Lectureship was announced on April 25, 1988 at a surprise champagne reception held in Professor Büchi's honor at the MIT Faculty Club. This endowed lectureship fund was provided by many generous friends, coworkers, and former students of Professor Büchi, and recognized his career-long association with MIT Chemistry and his leadership in the field of organic synthesis.

A panel discussion, entitled "Women in Academia and Industry", was held on May 12, 1988, sponsored by Women in Chemistry. The panel featured several distinguished speakers from academia and industry, including the Department's Professor JoAnne Stubbe. Women in Chemistry was established in September, 1987, and has been meeting throughout the academic year. It is composed of women from all facets of the the Chemistry Department: students, faculty, and staff .

The Howard O. McMahon Fund for Physical Chemistry was announced on June 15, 1988, and established with the help of a gift from Helix Technology Corporation in honor of Dr. Howard O. McMahon, who received his Ph.D. from the Department in 1941. This endowment fund is intended for the support of physical chemistry in the Chemistry Department. Uses of the Fund income may include support for new faculty just starting their careers, fellowship support to graduate students, "seed" support for established faculty to pursue innovative research ideas, acquisition of capital equipment, or resources to design and build new instrumentation. Each McMahon Fellow will acknowledge research or publications carried out with the Fund's support.

PERSONNEL

Professor Mark S. Wrighton became Head of the Department on July 1, 1987, succeeding the previous Department Head, Professor Christopher T. Walsh, who was named Chairman of Harvard Medical School's Department of Biological Chemistry and Molecular Pharmacology. Mr. Marc Jones succeeded Mr. L.W. Ryan, Jr. as the Chemistry Department's Administrative Officer on June 15, 1987. Dr. William M. Davis joined the Chemistry Department on November 30, 1987 as the new Staff Crystallographer in the Departmental X-Ray Facility.

Changes in the School of Science organization, including the closing of the Department of Applied Biological Sciences, have provided an opportunity for the Chemistry Department to add substantial breadth and depth to the area of biological chemistry. Coming to the Department as full-time faculty are Dr. Alexander M. Klibanov as Professor of Chemistry and Dr. Douglas C. Youvan as Assistant Professor of Chemistry. Joining the Department as joint appointments with Whitaker College are Dr. John M. Essigmann, Associate Professor, Dr. Steven R. Tannenbaum, Professor, and Dr. Gerald N. Wogan, Professor. These individuals represent a qualitative improvement in the Department's effort in teaching and research.

Professor Robert A. Alberty was elected Secretary of the Division of Physical Chemistry of the International Union of Pure and Applied Chemistry.

Professor George H. Büchi was named Doctor der Naturwissenschaften, *honoris causa*, by the Swiss Federal Institute of Technology "in recognition of his outstanding research on the structure and synthesis of natural products", on October 21, 1987.

Professor Stephen L. Buchwald has been selected for a two-year grant as an Alfred P. Sloan Research Fellow to begin in Fall 1988. Professor Buchwald was also chosen to receive an unrestricted grant from Lilly Research Laboratories.

Professor Sylvia T. Ceyer was promoted to Associate Professor with tenure. She was chosen to be the recipient of the 1988 Recognition Award for Young Scholars given by the American Association of University Women's Education Foundation on June 25, 1988. In addition, Professor Ceyer was presented with the Everett Moore Baker Award for Excellence in Undergraduate Teaching at the MIT Awards Convocation held on May 4, 1988.

Provost and Professor John M. Deutch was named to the Karl Taylor Compton Chair by President Paul E. Gray.

Professor Robert W. Field was the recipient of the 1988 Earle K. Plyler Prize in Molecular Spectroscopy sponsored by the American Physical Society. He was cited for his seminal contributions to molecular spectroscopy, especially in the treatment of perturbations and electronic structure in diatomic molecules and the development of important double resonance techniques.

Professors Frederick D. Greene, II and Robert J. Silbey were presented with the Chemistry Department's Graduate Student Council Teaching Award at the 1988 MIT Awards Convocation held on May 4, 1988.

Professor Daniel S. Kemp received the 1987-88 Science Council Teaching Prize for excellence in undergraduate teaching.

Professor James L. Kinsey received the E.O. Lawrence Award from the U.S. Department of Energy at ceremonies in Washington, D.C. on July 30, 1988. He was cited "for his application of spectroscopic methods to the study of molecules in the process of dissociating, which provides both a dynamic and a structural picture of chemical reactions".

Dr. Peter T. Lansbury, Jr. joined the Department's organic chemistry faculty on January 1, 1988, as Assistant Professor of Chemistry. He has been designated a Faculty Intern by Merck & Company, Inc. in connection with the Harvard/MIT Chemistry Faculty Intern Program. Professor Lansbury has also received a Dreyfus Foundation Grant for newly appointed faculty.

Professor Stephen J. Lippard received the Senior U.S. Scientist Award of the Alexander von Humboldt Foundation, which will support an eight-month sabbatical leave in Germany.

Professor Satoru Masamune was elected to the American Academy of Arts and Sciences.

Professor Keith A. Nelson was promoted to Associate Professor with tenure. Professor Nelson was also selected as the winner of the 1988 Coblentz Award by the Coblentz Society for the excellence of his work on picosecond spectroscopy and stimulated Brillouin scattering.

Professor Dietmar Seyferth was the Paolo Chini Memorial Lecturer at the 20th National Congress in Inorganic Chemistry on September 16, 1987 in Pavia, Italy.

Professor K. Barry Sharpless was appointed Arthur C. Cope Professor of Chemistry on December 1, 1987. Professor Sharpless received a 1987 Guggenheim Fellowship for study of new ligands to bind metal atoms in catalyst molecules. He was also the recipient of the Harrison Howe Award at the 17th Northeast Regional Meeting of the American Chemical Society.

Professor John C. Sheehan (Emeritus) gave the Memorial Lecture at a symposium dedicated to the late Professor Hamao Umezawa on November 25, 1987, in Tokyo, Japan.

Dr. JoAnne Stubbe, formerly of the University of Wisconsin (Madison), joined the MIT's biochemistry faculty on July 1, 1987 as the Ellen Swallow Richards Professor of Chemistry. She has also been awarded a Merck & Company Inc. Postdoctoral Fellowship in support of her research program.

Professor John S. Waugh received the Institute's 1988-89 James R. Killian, Jr. Faculty Achievement Award on April 20, 1988, for his fundamental pioneering contributions to the theoretical foundations and instrumentation of nuclear magnetic resonance. Professor Waugh also received a 1987 Distinguished Alumni Award from his *alma mater*, the California Institute of Technology.

Professor Mark S. Wrighton was chosen to receive the 1988 American Chemical Society Award in Inorganic Chemistry. On May 11, 1988, Professor Wrighton was elected to the American Academy of Arts and Sciences.

IN MEMORIAM

Professor Charles Gardner Swain, a member of the Department of Chemistry since his 1946 American Chemical Society Fellowship in the laboratory of the late Arthur C. Cope, died on March 10, 1988 after a brief illness. He taught at MIT as an Instructor from 1947 to 1948, when he was appointed Assistant Professor of Chemistry. He was promoted to Associate Professor in 1952, and Professor in 1958, retiring in 1986 as Professor Emeritus. Professor Swain's major areas of research were physical organic chemistry and the mechanism of reactions. He published many papers on the kinetics and mechanism of nucleophilic substitution, enolization, organometallic reactions, oxidations, and other organic reactions. His early work on the earliest working model of a bifunctional enzyme catalyst for mutarotation of glucose, demonstrating the same kinetics and essential features as the natural enzyme, continues to be cited in much later publications. One of his subjects in chemistry included computer programming as early as 1960 and was considered notable for its emphasis on quantitative relationships. Professor Swain held a Guggenheim Fellowship at University College, London and Oxford University in 1954-1955, and won the American Chemical Society's Award in Petroleum Chemistry in 1957.

NEW CHEMISTRY COURSES

In the Fall of 1987, Professor Dietmar Seyferth offered a Special Topics subject in materials chemistry, 5.066, featuring lectures by many distinguished industrial chemists. This new course provided an opportunity for students and faculty from the Department and the Institute with an opportunity to learn about the challenges in industrial innovation that depend on chemistry. In the Spring semester, Professor Rick L. Danheiser offered the Undergraduate Seminar 5.S12, "Frontiers in Chemical Research", featuring members of the Chemistry faculty speaking about their current research programs. In the same semester, Professor JoAnne Stubbe offered 5.067, a Special Topics course in biochemistry entitled "Enzyme Reaction Mechanisms".

GRADUATE STUDENTS

The Master of Science degree was awarded to 4 people in the 1987-88 academic year. A total of 40 Ph.D. degrees were awarded: 7 in September, 16 in February, and 17 in June. To date, 1892 Ph.D. degrees and 414 Masters degrees have been awarded by the Department of Chemistry. The following graduate students were particularly distinguished: Ms. Denise Schneeberger, a first year graduate student, won a Phi Kappa Phi Prize for graduate study in physical chemistry. Mr. David Jonas of the Field research group was selected to receive a 1988 AT&T Bell Laboratories Ph.D. scholarship. Mr. Ralph B. Nielsen of the Buchwald group received a 1987-88 Arthur D. Little Fellowship. Dr. James G. Bentsen was selected for an American Cancer Society Fellowship. The American Physical Society's Conference on Physical Electronics awarded its Nottingham Prize to Mr. John D. Beckerle of the Ceyer research group, in recognition of the best student paper at the conference. Mr. Qingyun Yang, also of the Ceyer group, was awarded an American Vacuum Society Student Prize in recognition of excellence in graduate research in November of 1987. Mr. David Albagli of the Wrighton research group was chosen to receive a 1988 MIT-Japan Science and Technology Program Prize. Mr. Martin O. Schloh, also of the Wrighton group, was selected to receive a 1988 Energy Research Summer Fellowship from the Electrochemical Society.

UNDERGRADUATE STUDENTS

Bachelor of Science degrees in Chemistry were awarded this year to 25 undergraduates. Most of the graduates will be attending graduate school in chemistry, medicine, or related disciplines, or have taken industrial employment.

The following awards to Chemistry undergraduates were announced on May 2, 1988 at the Chemistry Department Senior Recognition Dinner. The 1988 recipients of the Alpha Chi Sigma Award, given for achievement in research and scholarship and for service to the Department, were Ms. Anne M. Baranger, Mr. Seth N. Brown, and Ms. Marcia B. France. The 1988 Merck Index Award recipients were Mr. Jeffrey T. Finer, Mr. Andre S. Raw and John C. Stellwagen in recognition of their outstanding scholastic achievement. Mr. Henry W. Long will be this year's invited participant in the DuPont Summer Research Program. Mr. Brown, Mr. Finer, Ms. France, Mr. Raw, and Mr. Stellwagen have also been invited to join MIT's Xi Chapter of the Phi Beta Kappa Society. Other awards to undergraduates were as follows: Ms. Marcia France was the recipient of the American Institute of Chemists Student Award, presented on April 26, 1988 at Boston College, and was chosen to receive the Association of MIT Alumnae Award, which was presented to her at the MIT Awards Convocation on May 4, 1988. Mr. Seth N. Brown was also an award recipient at the May 4 Awards Convocation, winning the Karl Taylor Compton Prize in recognition of his outstanding contributions in promoting high standards of achievement and good citizenship within the MIT community. Ms. Anne M. Baranger was a 1987 Norris Summer Scholarship recipient, supported by the American Chemical Society's James Flack Norris Memorial Trust Fund. The four new members of the MIT chapter of Phi Lambda Upsilon, the national chemistry honor society, are Ms. Cindy Wang, Mr. Paul Chow, Ms. Irene Kuo, and Mr. Robert Rich.

DISTINGUISHED VISITORS

The Chemistry Department was privileged to host three visiting professors in residence in endowed lectureships during the past academic year. The 1988 Procter & Gamble Lecturer in the Chemical Sciences was Professor Stuart L. Schreiber of Yale University. Professor William H. Miller of the University of California at Berkeley was this year's Arthur D. Little Visiting Lecturer in physical chemistry. Professor Hisashi Yamamoto of Nagoya University (Japan) was this year's Karl Pfister Visiting Professor in Organic Chemistry. In addition, Professor Gordon Bates of the University of British Columbia taught the latter half of Chemistry subject 5.43 with Professor Satoru Masamune during his sabbatical visit to the Department in the Spring semester.

MARK S. WRIGHTON

Department of Earth, Atmospheric, and Planetary Sciences

FACULTY AND RESEARCH STAFF

On July 1, 1987, Professors Marcia McNutt and Paola Rizzoli were promoted to Associate Professor with tenure. Also on that date, Professor Kip Hodges became untenured Associate Professor, and Dr. Edward Dunham was promoted to Principal Research Scientist. In January, 1987, Professor William Young left the department to return to Scripps Institution of Oceanography in La Jolla, California. Two new faculty arrived in early 1988 - Professor Alan Plumb, atmospheric dynamicist, and Professor John Grotzinger, sedimentologist. A new planetary scientist, Professor Richard Binzel, will join the department on August 1, 1988. Promotions that will take effect July 1, 1988, include the following: Professors Kerry Emanuel and Glenn Flierl to Full Professor, Professor Jack Wisdom to Associate Professor with tenure, and Professors Brian Evans and Leigh Royden to untenured Associate Professor.

Honors

The Helen Warner Prize of the American Astronomical Society was presented to Professor Jack Wisdom in 1987, subsequent to his receipt of the Society's Harold Urey Award in 1986. In May, 1988, Professor Marcia McNutt received the American Geophysical Union's prestigious Macelwane Medal, in recognition of her work on the thermal and mechanical properties of the lithosphere and the nature of isostatic compensation beneath the oceans and continents.

ENROLLMENT

Our graduate enrollment for the academic year just ended was 179, 48 of whom were Joint Program students based at Woods Hole Oceanographic Institution. The undergraduate enrollment was 30. The annual geology/geophysics field camp in California and the astronomy field camp in Arizona took place in January, 1988.

RESEARCH

Geology/Geochemistry

Professors Clark Burchfiel and Leigh Royden spent four weeks mapping in Tibet with Chinese colleagues, in an area which included the north slopes of Mount Everest. They found clear evidence of several episodes of low-angle normal faulting, indicating northward slumping of higher elements in this generally collisional terrane. Professors Burchfiel and Royden, together with Professor Kip Hodges, will return to the same area for four weeks in September, 1988, to complete the project.

Mineralogical research by Professor Roger G. Burns has included studies of secondary minerals forming in the proposed repository for high level nuclear waste in Nevada. Electron and ion microbeam techniques showed that glass shards in vitric tuffs at Yucca Mountain become hydrated by groundwater and recrystallize to zeolites and clay silicates. These minerals are assumed to be capable of immobilizing radioactive isotopes should leakage occur from the repository. To test this assumption, cation exchange experiments performed on clinoptilolite, heulandite, and mordenite crystals occurring in rocks adjacent to the repository indicated that there are crystallographic controls on the uptake of cesium into the zeolites. They may be inefficient at immobilizing toxic radionuclides leaking into groundwater at Yucca Mountain.

Field, petrologic and geochemical studies of lavas forming across strike stratovolcanoes in the Chilean Andes have been a joint project of Professor Fred Frey and R. Hickey (Florida International University) and Chilean colleagues. Recent results show that the lava compositions reflect a west to east decrease in a component derived from the subducted slab. These results are providing constraints on the links between subduction of oceanic crust and volcanism on the overriding continental plate.

Professor Tim Grove's group has been using the results of elevated pressure phase equilibrium experiments on ocean floor basalts to constrain the processes of magma generation and evolution at oceanic spreading ridges. Work this past year has concentrated on a small axial volcano, Serocki Volcano, on the mid-Atlantic ridge at 22°55' N. Serocki Volcano was drilled during Leg 109 of the Ocean Drilling Program and mapped and sampled by the submersible ALVIN. Lavas erupted from Serocki Volcano show a systematic change in chemical composition. The group's high pressure experimental results show that this compositional variation is produced by differentiation in a magma reservoir at depths of 15 to 18 km in the upper oceanic mantle.

Professor Leigh Royden, with graduate student Lisa Block, has found that the geometry of mid-crustal fault surfaces, brought to the surface by young extension and thinning of the upper crust, imply that the lower crust deformed by ductile flow during the last 30 million years in the southwestern United States. This appears to be different from the behavior of the lower crust in most other continental areas, where it appears to be strong. The controlling factor is probably the high crustal temperatures present in the southwestern United States.

Using the ion microprobe, Dr. Nobu Shimizu conducted a detailed study of trace element characteristics of garnet inclusions in diamonds from the Finsch kimberlite pipe in South Africa. The peridotite-suite garnets are characterized by a strong LREE enrichment, depletions of Ti and Zr relative to REE, and large variations of trace element concentrations accompanied by a constant Mg/Fe ratio. It is suggested that garnets and host diamonds grew as a result of metamorphic decarbonation reactions, with garnet quantitatively incorporating trace elements of the local system. It is also suggested that the trace element traits of the local systems resemble those of the modern sub-oceanic lithosphere, indicating types of metasomatism prevalent through geologic time and space.

Professor John Southard has started a program of experiments on sediment bed forms in oscillatory flows in a new kind of laboratory flow duct, to simulate conditions at the seabed during extremely intense storms. The early phases of this work have already led to some major advances in the interpretation of depositional environments of marine sandstones in the ancient sedimentary record.

Geophysics

Dr. Arthur Cheng has been working on the attenuation of Stoneley wave in sonic logging across open fractures. At sonic logging frequencies of a few kilohertz, a parallel plate fracture does not obey the cubic law, and the hydraulic conductivity is roughly linearly dependent on the fracture aperture. This model fits the laboratory results of model logging experiments with both horizontal and vertical fractures.

Dr. Vernon Cormier has been investigating the effect of slab diffraction in seismic body waves, using asymptotic methods of seismogram synthesis. The results show that slab diffraction can be observed in a wide azimuthal range on the descending side of the slab. Modeling of this waveform distortion will help constrain models at slab penetration and deformation beyond the seismicity cutoff at 650 km. Dr. Cormier has also conducted theoretical research leading to improvements in the Gaussian beam technique of seismogram synthesis.

Professor Brian Evans is investigating pressure solution processes in halite, calcite, and quartz; the brittle-plastic transition in carbonates, peridotites, and diabase; and grain boundary migration in calcite. During the transition to plastic behavior in a deforming limestone, the partitioning of energy between brittle and plastic processes, as judged from stereological measurements of the microstructure, shows systematic trends with increasing pressure and strain. However, it is clear that even where brittle cracking contributes only a small amount to the total inelastic strain, the strength is still profoundly affected by increasing pressure.

Professor Thomas Jordan and his students have been working on a variety of problems related to the structure of the earth's mantle and the dynamics of large earthquakes. He and graduate student Gregory Beroza have developed a technique which uses the energy observed in the earth's very long period free oscillations to identify seismic events whose time constraints are significantly larger than ordinary earthquakes. Understanding these "slow earthquakes" is providing new insights into the physics of earthquakes in general. Professor Jordan and graduate student Ann Sheehan have recently shown that the slow release of seismic energy from deeper, more ductile layers may trigger the rapidly propagating ruptures of some large earthquakes.

Dr. Robert King, Dr. Yehuda Bock, and Professor Thomas Jordan, in collaboration with colleagues at Caltech, UCLA, and UCSD, 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 the first of a series of measurements to be performed over the next five years, they measured the relative positions of 20 sites with a precision of 5-15 mm.

Professor Ted Madden and colleagues have been using their telluric array data in Hollister, California, in conjunction with the magnetic observatory in Fresno, California, to study the ocean-continent boundary effects on magnetotelluric fields. Their analysis shows that good determinations can be made of oceanic crustal resistivities and oceanic mantle conductivities from a land-based measurement. They are in good agreement with the only previous measurement of oceanic crustal resistivities (resistivity thickness product) which are quite high, and they found high upper mantle conductivities but with low gradients in the top 900 kilometers, with a distinctive increase of conductivity below around 600 kilometers. The upper mantle effects can be explained by some partial melt which decreased with depth. The deeper conductivity increases have been observed before, and probably require a phase change as the temperature gradients are too small to cause such variations.

Volcanism in French Polynesia continues to be the focus of research for Professor Marcia McNutt and her students. Using information gathered during a recent oceanographic expedition to the Marquesas Islands, they have solved the long-standing problem of why that island group departs in azimuth from the N64°W trend of all other young volcanic chains in the Central Pacific. Their explanation has led to a revision in models of the nature of thermal plumes ascending from the deep mantle.

Professor Jason Phipps-Morgan has continued his research on the thermal and mechanical structure of mid-ocean spreading centers while starting new research projects on small-scale convection within the upper mantle and on melt migration within the mantle. The latter work has led to the exciting possibility that mantle deformation induces an anisotropic melt permeability to the mantle, which in turn is the cause of the narrow spatial zone of volcanism at mid-ocean spreading centers and oceanic hotspots.

Professor Daniel Rothman has created a new numerical method for modeling immiscible two-phase flow. The technique, based on lattice-gas hydrodynamics, should provide new insight into the physics of two-phase flow in porous media - in addition to providing a method for the study of a variety of other problems involving fluid mixtures and interfaces.

Professor Sean Solomon and his students have been utilizing networks of ocean-bottom seismometers and seismic tomography techniques to study the tectonic behavior and to determine the three-dimensional crustal structure along mid-ocean ridges. A microearthquake experiment on a large-offset transform fault in the Atlantic indicates that the least compressive stress in the adjacent lithosphere is oriented perpendicular to the fault zone, consistent with the hypothesis that major strike-slip faults are zones of lithospheric weakness. The group has recently returned from an expedition to image the three-dimensional structure of the postulated crustal magma chamber along the crest of the East Pacific Rise.

Professor M. Nafi Toksöz has developed a tectonic model of the eastern Mediterranean based on the interactions of the Arabian, African and Eurasian plates. This model explains the earthquake mechanisms, active faults and crustal block motions.

Meteorology

Professor Randall Dole has performed observational analyses demonstrating that major cases of atmospheric persistence are associated with a relatively small number of recurrent large-scale flow patterns. These flow patterns are related to major anomalies in surface temperatures and significant shifts in the locations of maximum storm activity over the Northern Hemisphere.

Professor Kerry Emanuel has continued his study of air-sea interaction theories for the development of long-period oscillations of the equatorial atmosphere, and also his study of small-scale cyclones that form over the polar oceans during the arctic night.

Dr. Bruce Fegley has made the first experimental measurements of the gas-solid reactions forming CaSO_4 under Venus surface conditions. This rate coupled with a steady state model and Venera chemical analyses of the Venus surface gives an estimate of $1 \text{ km}^3/\text{year}$ for the present-day volcanism rate on Venus required to replenish the SO_2 lost from the atmosphere by this reaction.

Professor Richard Lindzen is studying aspects of dynamic meteorology ranging from the basic mechanism of shear instability to the reasons for the 100K year cycles in glaciation. Most recently, he has developed simple models for the influence of sea surface temperature distribution on tropical precipitation, for the influence of subtropical winds on stationary weather patterns at middle and high latitudes, and for the abrupt transitions between summer and winter circulation patterns.

Professor Reginald Newell's group recently published work on total ozone showing that, in addition to the Antarctic ozone hole, there have been substantial ozone reductions since 1983 in middle and high latitudes of the Northern Hemisphere which may be related to the El Chichon volcanic eruption of 1982. The Southern Hemisphere reductions are larger, while Northern Hemisphere reductions are smaller in the past few years.

Professor Peter Stone and his NASA colleagues have used their three-dimensional numerical global climate model to forecast the probable changes in climate in the coming decades caused by increases in greenhouse gases. They find that the greenhouse warming should be clearly identifiable in the 1990s and that the global warming in the decade 2000-2010 will reach the level attained at the peak of the current and previous interglacial periods.

Professor Earle Williams' Doppler radar and electrical observations of thunderstorms have shown a close relationship between lightning type and the phase of the convective cycle. The observation that the peak intracloud lightning rate precedes the maximum low-level outflow by 5-10 minutes suggests that ice is responsible both for the electrification and for the dynamics of the outflow.

Oceanography

Professor Ed Boyle has produced a new model to account for the 30% reduction of atmospheric carbon dioxide during the Wisconsin glaciation. In his model, changes in deep ocean circulation transfer carbon dioxide into the deepest waters of the ocean. The resultant CO₂-induced acidity dissolves carbonate sediments, causing the ocean to become more alkaline. The more alkaline seawater draws CO₂ from the atmosphere into the ocean. The model is supported by his evidence on the chemical composition of fossil shells from deep sea sediments.

Professor Paola Malanotte-Rizzoli has continued her studies on the assimilation of different data types into Models of the Ocean General Circulation (OGCM). Data assimilation into OGCM is one of the central objectives of WOCE (the World Ocean Circulation Experiment). She has found that: (1) The knowledge of integral properties like the total transport is much less effective than the knowledge of the interior density field in reducing model errors. If the density field is known, coarse horizontal resolution of data stations can be reached before worsening significantly the model estimates. If only the transport is known, half resolution of the data stations has the immediate effect of increasing model errors. (2) The efficacy of altimetric data (surface pressure) in improving the estimate of the circulation in the deep layers is strongly dependent on the assimilation technique used, as the model itself is not an efficient dynamical extrapolator of the surface information.

Professor Carl Wunsch and his students have been studying the use of transient tracers for the purpose of deducing the oceanic general circulation. They have developed a general mathematical framework for deductions from such "dyes" based upon control theory methods.

Planetary Science

Professor Charles Counselman's group developed an improved method of determining earth satellite orbits, which enables regional displacement of the earth's crust to be measured with precision of a few parts in 10⁸.

Professor Jim Elliot, Dr. Edward Dunham, and their students prepared for and successfully observed the occultation at a star by Pluto. The preparation for this event involved taking and analyzing astrometric data to allow the unusually difficult prediction of the circumstances of the occultation to be made, and also the development of a new method of taking occultation data with an extremely sensitive imaging photometer. The occultation was successfully observed with the Kuiper Airborne Observatory over the ocean south of Samoa. This observation is the first unambiguous detection of an atmosphere on Pluto. Further analysis of the data will result in measurements of temperature density and other physical parameters of the Plutonian atmosphere. More detailed analysis of the astrometric observations should yield the ratio of the masses of Pluto and its satellite, Charon.

Professor Jack Wisdom has numerically integrated the motion of the outer planets for 845 million years with the Digital Orrery. This integration indicates that the motion of the planet Pluto is chaotic. He has also carried out a systematic study of the tidal evolution of the Uranian satellites. He found that mean-motion resonances among these satellites are associated with significant chaotic zones. The anomalously large 4° inclination of Miranda arises naturally upon passage through one particular resonance. The requirement that this resonance has been encountered places stringent limits on the rate of internal dissipation in Uranus.

WILLIAM F. BRACE

Department of Mathematics

ACADEMIC PROGRAM

There were 195 undergraduates majoring in mathematics and 128 graduate students. Of the undergraduate majors, 137 were registered for the general mathematics degree (XVIII), and 58 for the mathematics with computer science degree (XVIII-C). The Bachelor of Science was awarded to 70 students, including 7 second majors. There were three recipients of the Master of Science, all in pure mathematics. Nineteen received their Doctor of Philosophy in mathematics, with 14 in pure mathematics and 5 in applied mathematics.

Core Curriculum

Nationally, there is a movement to experiment with new ways to teach calculus. This is partly a response to the high national drop-out rate in this subject. There is also a felt need to incorporate symbol-manipulating calculators into calculus, since they are likely to become a standard tool for working engineers. Here at MIT, new textbooks are currently being written: one for 18.02 (multivariable calculus) by Hartley Rogers; and next fall there will be a new version of 18.01, called 18.01A, based on notes being written by Gilbert Strang. We will be experimenting as well with a calculus workshop, based on currently available commercial calculus software. In another direction, the experiment in linking calculus and physics recitations described in last year's President's Report continues, and -- in a somewhat reduced scale -- is a regular feature of the calculus scene.

This was the second year in which the differential equations course (18.03) had Athena problems to be done by all students (about 500/semester). About half of the problem sets now have an Athena component, based on menu-driven software packages written here that plot direction fields and integral curves, and that plot the trajectories of a 2 x 2 non-linear system, given initial conditions.

FACULTY

Professor Peter Huber of the Harvard Statistics Department has accepted a tenured professorship, and will be joining the Department this summer. Professor Huber is well-known for his earlier pathbreaking work in the field of robust statistics, as well as his current work in "projection pursuit": computerized searching for meaningful one- and two-dimensional projections of multidimensional data points.

Dan Henningson will be coming as Assistant Professor of Applied Mathematics. His field is in computational fluid dynamics. He received his Ph.D. at M.I.T. a year ago in XVI (Aeronautics and Astronautics) and has spent this year in Stockholm.

Ehud Hrushovski will be a new Assistant Professor in logic, specializing for the moment in model theory. He is now at Princeton, combining an instructorship with an NSF Fellowship. He will be on leave from M.I.T. until the spring semester.

Zhenfang Zhou, who has just finished his second year as Moore Instructor, will start a three-year appointment as Assistant Professor. He is an analyst, and is currently working in non-linear partial differential equations.

Assistant Professor David Jerison was promoted to Professor. His specialties are partial differential equations and Fourier analysis. He will also be assuming the duties of Undergraduate Chairman, taking over from David Vogan.

Assistant Professor Nicholas Warner was promoted to Associate Professor. He specializes in theoretical physics, supergravity theories, and supersymmetry.

Professor Daniel Quillen resigned his professorship to remain at Oxford, where he has been on leave the last three years.

Assistant Professor Er-Cheng Tsai resigned to accept an appointment in the Physics Department at the National Taiwan University.

Professor Richard Schafer retired this June. Professor Schafer has been known for 40 years -- the last 29 of them at MIT -- as one of the world's experts in non-associative algebras, both for his early work on representations of Lie algebras, and later work on Jordan algebras. His book in this area continues to be a standard reference. In addition to teaching at one time or another all of our algebra courses, Professor Schafer served for many years as Deputy Head of the Mathematics Department, and he was responsible for developing many of the policies and procedures the Department uses today. Professor Schafer plans to settle with his wife in suburban Washington D.C., after first attending a research conference on Jordan algebras in W. Germany.

Faculty on leave during the year were: Bertram Kostant (Spring, Mathematical Sciences Research Institute), Daniel Quillen (year, Oxford), Hartley Rogers (Spring), Isadore Singer (year, University of Paris, France), Harold Stark (Spring, University of California, San Diego), Michele Vergne (year, Centre de Mathematiques, Ecole Normale Superieure, France), David Vogan (Spring, Mathematical Sciences Research Institute), David Jerison (year, Mathematical Sciences Research Institute), C. Fred Pearson (Spring, University of Washington), Ruben Rosales (year, Stanford University), Michael Sipser (Spring, Hebrew University, Israel), Nicholas Warner (year, C.E.R.N., Switzerland).

Visiting Faculty in the Department this year were: Greta Ljung (Boston University), Iris Mack (Ph.D., Harvard), Egon Schulte (Dortmund University, West Germany), and Eva Tardos (Eotvos University, Hungary). Joining the Visiting Faculty this Fall will be Stella Ashford from Southern University and Mendel Fygenon, who was with the Department this past year as Instructor, Applied Mathematics.

Professor Daniel Kleitman will succeed Professor Willem Malkus as Chairman of the Applied Mathematics Committee. Professor Malkus served in this position for the last three years.

Professor Richard Melrose will continue as Chairman of the Pure Mathematics Committee, Professor James Munkres as Chairman of Undergraduate Advisors, and Professor Sigurdur Helgason as Chairman of the Graduate Committee. As stated, Professor David Jerison will be the new Undergraduate Chairman.

FACULTY HONORS AND AWARDS

Professor Michael Artin has been appointed to the Wiener Professorship for a five-year term. The Norbert Wiener Professorship was created by the M.I.T. Administration around 1970. This chair is awarded based on the recommendations of a committee, which consults with senior faculty. Professor Artin was selected primarily because of the distinction and influence of his work in algebraic geometry and, more recently, ring theory. However, consideration was also given to his work as a Ph.D. adviser (about 25 graduate students, many of whom are having distinguished careers), and to his service both in the Department and in the national mathematics scene, as the first Chairman of the NRC Board on Mathematical Sciences and the founding Editor-in-Chief of the new Journal of the A.M.S..

Professor Victor Guillemin received a Guggenheim fellowship.

Assistant Professor Antonio Sanchez was awarded a Sloan fellowship.

Assistant Professor Nicholas Warner also received a Sloan fellowship.

Professor Isadore Singer was awarded the Wigner medal in Group Theory and Fundamental Physics.

Professor Richard Stanley was elected a member of the American Academy of Arts and Sciences.

Professor David Shmoys received the Graduate Student Council teaching award in the Department of Mathematics.

STUDENTS

Two graduate students, Yu-Ching You and Maciej R. Zworski were selected by a national committee to receive Alfred P. Sloan Doctoral Dissertation Fellowships.

The annual Jon A. Bucsela Prize, given by the Department of Mathematics for distinguished scholastic achievement, professional promise, and enthusiasm for mathematics, was awarded to senior undergraduates Leonard J. Schulman and Jeffrey S. Silver.

Michael C. Morgan, a course 18 senior, was awarded a National Science Foundation Graduate Fellowship. Because of his award, the Department was given a NSF Incentives for Excellence Scholarship Prize of \$1,000 to be reawarded to "undergraduate minority students...in recognition of their scholastic excellence and to further their continued study." The Prize was awarded to Course 18C junior Mark B. Moss.

ARTHUR P. MATTOCK

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), Center for Materials Science and Engineering (CMSE), 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 1987-88 the total number of the Faculty was 88. The following members of the Faculty received promotions: to Associate Professor without Tenure, Janos Polonyi; to Professor with Tenure, A. Nihat Berker. Four new Assistant Professors joined our Faculty: Katherine Freese, John Graybeal, Simon Mochrie, and Jonathan Wurtele. One new Senior Research Scientist was hired, Earl Marmar. Three members of the Faculty retired: David H. Frisch, Stanislaw Olbert, and Malcom Strandberg.

Faculty on leaves or sabbaticals during the year included Professors Ulrich Becker, Eric R. Cosman, Ali Javan, Gabriel Kotliar, Patrick Lee, Malcom Strandberg, and Toyochi Tanaka. Faculty Sloan Fellows included Professors Edmund Bertschinger, Edward Fahri, Mehran Kardar, Gabriel Kotliar, Janos Polonyi, and John Tonry.

A number of our faculty received awards during the past year. Professor Samuel C.C. Ting received the prestigious 1988 De Gasperi Prize (Italian Republic), the first non-Italian to do so. Similarly, Professor A.P. French was selected by The Institute of Physics (London) to receive the august Bragg Medal and Prize. Professor Mildred Dresselhaus was chosen as the 1987 holder of the James R. Killian, Jr. Faculty Achievement Award. Other awards and honors received by Physics Faculty follow. Professor Robert J. Birgeneau was corecipient of the 1988 Bertram Eugene Warren Award (American Crystallographic Association). Professor George Benedek was elected a Fellow of the American Association for the Advancement of Science. Professors Nihat Berker and Edward Farhi received the 1987 Buechner Faculty Teaching Prizes. Professors Edmund Bertschinger, Mehran Kardar, Aneesh Manohar and Janos Polonyi were awarded Sloan Research Fellowships. Professor Bruno Coppi received the 1987 James Clark Maxwell Prize (The American Physical Society (APS)) and the 1987 Dante Gold Medal (Dante Society). Professor Emeritus Robley D. Evans received the William D. Coolidge Award (American Association of Physicists in Medicine). Professor Robert Jaffe received the 1988 Student Council Teaching Award for Physics. Professor Henry Kendall was elected a Fellow of the American Association for the Advancement of Science. Professor Daniel Kleppner was elected to the American Academy of Arts and Sciences. Professor Stephan Meyer was named as the first holder of the Class of 1942 Career Development Professorship. Professor Philip Morrison was chosen to receive the Andrew Gemant Award (American Institute of Physics).

With regard to student honors, the 1988 Buechner Student Teaching Prizes were awarded to Wayne Lewis and Derin Sherman. Christopher Carone received the 1987 Joel Orloff UROP Award. Matthew Mayberry was chosen for the 1987 Simon Ramo Award (APS). Robert W. Lourie received the Demos Prize, given annually for outstanding doctoral research carried out at the BLA. David C. Williams, a graduate student who worked at the LNS as a Northeastern coop student received Northeastern University's Alcott Award. Thirteen students were elected to Phi Beta Kappa: Thomas L. Clune, Glenn E. Cooper (also Electrical Engineering and Computer Science), Vincent H. Crespi, Thomas R. Junk, Jens O.M. Karlsson, Andrew H. Miklich, Daniel M. Mittleman, Samuel T. Osofsky, Tomas J. Pavel (also Mathematics), John S. Seo, Lenny Sheet (also Electrical Engineering and Computer Science), Siang-Chun The, and Julie A. Theriot (also Biology).

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 246, and the number of graduate students was 293. The number of degrees awarded totaled 73 S.B., 6 S.M., and 40 Ph.D.

CURRENT RESEARCH

Astrophysics Division

Research in the Astrophysics Division is concerned with the observation and analysis of a wide variety of astrophysical phenomena including the interactions of the solar wind with planetary magneto spheres, the structure and evolution of stars and binary systems, quasi-periodic oscillations in the brightness of X-ray stars, hot gas in clusters of galaxies, the microwave background radiation, gravitational radiation, cosmic strings, and the development of structure in the early universe. Major efforts are devoted to the instrumentation and use of ground-based and space-based observatories. Theoretical research is carried out on topics ranging from plasma physics in the solar system, to cosmology and the large-scale structure of the universe.

1. High-Energy Astrophysics

Research activities in observational high energy astrophysics now rely primarily on the extensive archives of X-ray observations obtained with the US and European satellite observatories that were developed and operated during the decade from 1975 to 1985. One group in collaboration with associates in Holland and Germany is using data from the European satellite EXOSAT to investigate the X-ray phenomena of neutron stars in low-mass binary systems, in particular the X-ray bursts and the quasiperiodic variations in X-ray intensity which many of these systems generate. These studies will be extended with new data recently acquired from the Japanese X-ray satellite, GINGA, in a guest observer program sponsored jointly by the Institute for Space and Aeronautical Science, Tokyo, and NASA. In another investigation, the systematic search for the optical counterparts of X-ray sources detected in the all-sky survey carried out during 1977-79 with the orbiting High Energy Astrophysical Observatory HEAO 1 is yielding about 40 new identifications per year in a program of optical observations. The search, which is being conducted with telescopes in both the Northern and Southern Hemispheres, is aimed at compiling by early 1990 a comprehensive catalog (~600) of identified X-ray sources. Work has continued in the study of cooling flows in the X-ray emitting gas in elliptical galaxies and clusters of galaxies using the archives of X-ray spectroscopy and imaging data from the Einstein Observatory that operated for two years from 1979 to 1981. Related optical observations of emission lines from these objects have been made at the McGraw Hill Observatory. An extensive set of numerical models of galactic cooling flows have been used to explore the importance of various physical parameters, such as heating and mass injection rates. This research has made it possible to set limits on the possible masses of giant black holes in the centers of giant elliptical galaxies. Also under study are the X-ray spectra of nearby active galaxies and quasars, and the physical conditions in supernova remnants as revealed by X-ray spectral diagnostics. There have also been further investigations of the atmospheric structure of the normal companions of X-ray stars in eclipsing binary systems using data on the attenuation of the X-ray brightness during eclipse transitions. Archival data from the MIT X-Ray Observatory on SAS 3 has been used to define the scale height of the atmosphere of HZ Herculis, the companion of the X-ray pulsar Her X-1, and new data on other X-ray binaries have been obtained in guest observations with the GINGA observatory.

2. Optical Astronomy

There is an ongoing investigation of the dynamical properties of elliptical galaxies and the nature and distribution of "dark matter". Recent results, derived primarily from optical observations with the 5m Hale Telescope of the Palomar Observatory, include establishing the existence of a massive black hole at the center of M32, and a detailed study of X-ray and optical observations of M87 which has provided new information about the extent and core radius of the dark halo, and has demonstrated that the globular clusters of that galaxy are in nearly circular orbits about its

center. A new method is being developed for measuring extragalactic distances. The technique, based on the measurement of small-scale variations in the surface brightness of elliptical galaxies, are expected to yield results that are more accurate and reliable than any other redshift-independent distance measurements.

3. Gravitational Radiation

The Gravitational Radiation Group has continued its work on the construction of the new 5-meter prototype gravitation wave antenna. The vacuum system and the in-vacuum optical tables have been tested and qualified. The system is now ready for the installation of a new interferometer. The first copy of the new suspension and vibration isolation system for the interferometer mirrors is being tested. Work has begun on a new laser stabilization scheme. Tests are being made on quiet, diode-pumped Nd: YAG lasers, as well as on a high power YAG laser pumped with lamps. The design of the control and data-logging computer system has been determined. The organization of the Caltech/MIT Laser Interferometer Gravitational Wave Observatory (LIGO) project has been strengthened through several administrative changes. Professor Rochus Vogt, former Provost of Caltech, is now the Director of the project. He holds the rank of Visiting Professor in the Physics Department at MIT. Under his direction, the engineering design of the large baseline facilities will be undertaken in the coming months. In addition, much tighter coordination of the laboratory research of the Caltech and MIT groups has been achieved.

4. Cosmology

Some of the deepest problems of the early universe and the evolution of structure involve the phenomena of chaos. New experimental results have been obtained on the three-frequency quasiperiodic transition to chaos which indicate that conjectures advanced over a decade ago may be true, namely, that the appearance of a third incommensurate frequency in a hydrodynamic system is in all likelihood accompanied by chaos. Further work on this problem is being undertaken because of its great potential importance for the understanding of hydrodynamic turbulence in astrophysics. The instruments for the Cosmic Background Explorer (COBE) satellite mission are undergoing preflight testing. Integration of the instruments into the flight dewar will occur in the fall 1988. The MIT group is closely associated with the Far-Infrared Absolute Spectrometer (FIRAS) which will measure the spectrum of the Cosmic Background Radiation (CBR) from one to 100 inverse centimeters. MIT is also involved in the characterization and analysis of the Diffuse Infrared Background Experiment (DIRBE) which will measure the absolute intensity of background radiation from one to 400 microns wavelength. The COBE satellite is scheduled for a Delta rocket launch in May 1989. In addition, the MIT Group has nearly completed the development of a four-channel balloon-borne CBR anisotropy experiment to measure CBR anisotropies in the range from two to 25 inverse centimeters on angular scales from four to 180 degrees with a sensitivity of a part in 10^5 . The gondola and flight hardware are complete and the instrument is currently being calibrated. The first flight is scheduled for September 1988. A 19 GHz balloon-borne maser experiment was successfully flown from Australia with 10 hours of excellent data. A second flight is scheduled for November of 1988 to make a complete map of the sky. These data will improve the model of the local astrophysical emission from our galaxy and thereby improve the measurements of the CBR anisotropy. In a new collaboration with the Goddard Space Flight Center, the MIT group plans to fly the four-channel instrument and a 1.5 meter balloon-borne telescope to measure the anisotropy on angular scales of 0.5 degrees. The experiment is being designed to detect anisotropies as small as a few parts in 10^6 . This experiment will fly in 1989.

5. Theoretical Astrophysics

Several studies have been made of the very early evolution of stars using both analytic and numerical techniques. In one study, the birth of an intermediate-mass star from collapsing interstellar clouds is being followed, in the hope that the internal structure of such stars will provide a clue to the violent flaring often observed. In a related project, the growth of circumstellar disks from infalling cloud material is being followed, to establish plausible initial condition for the growth of planetary systems. Studies of the formation and evolution of short period binary stellar systems which contain neutron stars are also being pursued. Models have been developed for the remarkable newly discovered 1.6 msec pulsar in a 9 hour binary system, the system containing the precursor of the supernova that exploded last year in the Large Magellanic Cloud, and the binary with the shortest known orbital period of 11 minutes in the globular cluster NGC6624. Investigations have continued in the possible

influence of cosmic strings in the formation of the large scale structure of the universe. Cosmic strings are thought to be among the possible products of the Big Bang, and great interest now focuses on the question of what the observable consequence of their existence might be.

6. Space Plasma Physics

The group is continuing the direct exploration and theoretical modeling of the dilute plasmas found in the solar system, from the near-Earth space environment to the outer reaches of the solar system. During this year, work continued on the interpretation of the Voyager data acquired in the magnetospheres of Saturn, Uranus, and Jupiter, and in the medium between those planets. At Saturn, the emphasis has been on a study of the thermal anisotropy of the magnetospheric plasma, which bears on the nature of the sources and sinks of plasma in this system, as well as on dynamical aspects of plasma transport. Further study of the data from the Uranus encounter has demonstrated that the magnetosphere during the Voyager 2 passage was in a state of dynamical change, similar to that produced by magnetic substorms at the Earth. At Jupiter, work has concentrated on obtaining a better understanding of the plasma "voids" observed near the Galilean satellite Ganymede; this has resulted in a better understanding of the response of the MIT plasma experiment to the often bizarre plasma environments it has encountered during its 11 year voyage. Studies are continuing on the large scale (temporal and spatial) changes in the solar wind over 30 AU. The plasma experiment on Voyager 2 remains healthy, and planning for the August 89 Neptune encounter is intensifying. Work has also begun on the solar wind plasma experiment which is to be flown on the WIND spacecraft in the 1990's as part of the international Global Geospace Study.

The Theoretical program of the new Center of Excellence in Theoretical Geo/Cosmo Plasma Physics, established under the University Research Initiative Program is now essentially fully staffed. This program is interdisciplinary and provides support for the work of theoretical plasma physicists, ionospheric and magnetospheric scientists, plasma astrophysicists, and numerical analysts, interacting with one another and with the international community (particularly experimental groups) engaged in space plasma activities. Current research topics include particle acceleration and diffusion, magnetospheric and ionospheric turbulence, accretion inflow and radio jets, wave generation and propagation in the geo/cosmo plasma environment, auroral processes, and the nonclassical polar and solar wind.

Atomic, Condensed Matter, and Plasma Physics Division

1. Atomic, Molecular, and Laser Physics

Using a novel detector comprised of superconducting electronics and a superconducting quantum interference device (SQUID), a single N_2^+ ion has been isolated and detected in an electromagnetic trap. Although single elementary particles (electron, positrons, protons) have been isolated before, this result is the first for a heavy molecular ion and opens the way to precision mass comparisons using single ions (present mass spectrometers need ~1000 ions). Preliminary measurements of the cyclotron frequency (inversely proportional to its mass) were made at a level of 10^{-9} , and indicate the possibility of measuring mass at the 10^{-11} level of precision, about 1000 times better than the current state-of-the-art. This level opens a new frontier in mass spectroscopy - weighing energy at the fractional eV level, and is relevant to such fundamental problems as the neutrino rest mass, the Avagadro constant, and the binding energies of molecular ions and highly ionized atoms.

The first radio frequency spectra from atoms confined in a magnetic trap have been obtained. These spectra were a diagnostic of the atoms' energy distribution, and showed that the sodium atoms were a hot (by our standards) 60 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.

Biomedical studies are in progress to develop a new type of catheter for "laser angioplasty", the removal of atherosclerotic plaque by means of laser light delivered via optical fibers. It has been demonstrated that fluorescence spectroscopy with both UV and visible excitation can be used to differentiate normal and atherosclerotic artery wall. Studies are underway to correlate spectroscopic features to chemical and structural tissue properties. A simple mathematical model has been developed which

accurately relates visible tissue fluorescence spectra to intimal thickness and tissue absorption properties. Using a fiber optic catheter, spectroscopic images of the interior of human cadaver arteries have been recorded. Such images clearly delineate regions of blood filled lumen, normal, and atherosclerotic tissue. Thus, it appears that laser angioplasty with spectroscopic guidance is feasible. Also, fluorescence decay measurements are in progress using the newly set up picosecond laser facility. These results, along with spectral features will help to identify different chromophores responsible for fluorescence.

Laser-induced nuclear orientation 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 μ s) ^{85}mRb atoms. The lifetime of this nucleus is a thousand times shorter than that of any previously studied by optical methods. Current experiments are underway to measure the quadrupole moment of this isomer as well as the angular correlation between the electron and the neutrino emitted in the β -decay of the parent nucleus.

Experiments for studying vacuum radiative level shifts and spontaneous emission line-widths of an atom in an optical resonator have been performed. In addition to showing enhancement and suppression of the atom's spontaneous emission rate, radiative level shifts have been demonstrated in the optical regime for the first time. Further experiments will include the use of a better cavity.

2. Condensed Matter Physics

Spin-polarized atomic hydrogen is a system which is predicted to remain a gas down to absolute zero of temperature. Previous experiments have shown that the gas can be destroyed through contact with walls. A trap has been developed which confines the atomic hydrogen by magnetic forces alone and completely isolates it from all surfaces. The gas in the trap has been cooled to a temperature of 1 millikelvin by an evaporative technique. The trap has stored atoms for as long as five hours, and densities of the order of 10^{13}cm^3 have been obtained. These advances open the way to the study of hydrogen in a new quantum regime. Atomic hydrogen at submillikelvin temperatures can provide an ideal system for studying the weakly interacting Bose gas and quantum transport phenomena. The new techniques are also expected to have important applications in atomic physics and ultra high resolution spectroscopy.

The MIT electronic structure group has successfully combined statistical mechanical renormalization group analyses with quantum electronic structure calculations to develop a theoretical formalism that enables theorists, for the first time, to study the statistical mechanics of real material systems, ab initio.

In the last year important improvements have been made in the accuracy and scope of renormalization-group and Monte Carlo renormalization-group methods. It will now be possible to study microscopic quantum mechanical models applicable to high- T_c superconductivity. Other recent works include a theory of quenched randomness at multicritical points and the derivation of a finite-temperature bicritical point in reentrant liquid crystals, both from a microscopic approach.

With the publication of the first measurements ever reported of magnetic fields generated by electrochemical reaction of metals in high conductivity solutions, the Specialty Materials Laboratory has fostered a new direction of corrosion research and a new application for superconducting device SQUID technology. The richness of fundamental information is its most dramatic in the noise spectra of the electrochemically-generated magnetic fields. It has been possible to obtain such spectra over a wide frequency range, to work backwards from them to the identification of source mechanisms contributing with specific behaviors, and to present suitable original theoretical models consistent with the observed data.

High reliability thin film circuit performance investigations jointly undertaken with Draper Laboratory are giving important results concerning 1/f noise associated with electromigration effects. There are clear indications in the 1/f noise of current flow that electromigrative behavior is underway. Correlation of this indicator to resistance changes has demonstrated the potential of 1/f noise to be predictive and therefore useful in circuit reliability studies. These results are folding back on the magnetic field studies of corrosion activity power spectra in a powerful way and on the understanding of the microscopic "anode/cathode" characters of surface regions.

Previously, it has been shown by the MIT liquid crystal group that the material 8OSI exhibits the sequence of phases smectic C \rightarrow smectic I \rightarrow smectic J. It was speculated that the smectic I phase was "a stacked hexatic", that is, a phase of matter with orientational long range order but only positional short range order in the planes; the smectic J phase was believed to be an ordinary crystal. These predictions were confirmed by high resolution synchrotron x-ray measurements. The experiments have now been extended to films of 8OSI with thicknesses of four and 23 molecules. The same phases are found to exist in these two dimensional systems; however, the hexatic I phase exhibits some characteristics which are uniquely two dimensional. These are the first experiments on two dimensional single domain hexatic liquid crystal phases.

Synchrotron x-ray diffraction studies have been carried out of the pure W (100) reconstruction transition as a function of temperature as well as the room temperature phases and phase transition of W (100) with submonolayer coverages of hydrogen. For clean W (100) it is found that below the transition temperature of 240 K, the $\sqrt{2} \times \sqrt{2}$ R45° diffraction peaks have an intrinsic width, larger than the instrumental resolution, corresponding to finite sized domains. Nevertheless, one is able to measure one and a half decades of change in the diffraction line-width, and three decades in the amplitude. The detailed dependences of the surface peak widths are consistent with the predictions of the two dimensional Ising model to leading order. It is also found that the diffraction peak is commensurate at all temperatures measured, above and below the transition temperature. For hydrogen-plated W (100) the data suggest a simple picture in which at very low coverages there is a trade-off with increasing coverage, analogous to that in a two-phase coexistence region, between hydrogen-poor and hydrogen-rich regions until a uniform but still disordered ($\sqrt{2} \times \sqrt{2}$ R45° -H) phase is attained. With further increase in coverage the surface layer exhibits a commensurate-incommensurate transition which, rather than being a solid-solid transition as previously assumed, is actually a lattice-gas melting transition into a domain-wall fluid phase. Such surface domain-wall fluid phases should occur commonly in chemisorbed systems. These experiments are the first studies of transition metal surface reconstruction using x-ray techniques.

X-ray reflectivity techniques have also been used to study the thermodynamic stability of simple metal crystal surfaces. Crystal surfaces can either be smooth or rough. A rough surface consists of many atomic steps and islands. On the other hand, a smooth surface is atomically flat. Furthermore there can be a roughening transition temperature (T_R), which depends on the crystal face in question, such that for $T < T_R$ the surface is smooth but for $T > T_R$ it is rough. According to simple theoretical estimates, Cu (110) is expected to be rough for temperatures immediately below the melting temperature (T_m). X-ray experiments were carried out on a sample of Cu that was cut at an angle of 0.8° away from the crystallographic (110) direction. At high temperatures ($T > 900$ K) the surface conforms to this "miscut" microscopically and consists of atomic steps separated by 90 Å. In this sense, it is indeed rough. At low temperatures, however, the steps agglomerate to expose step-free facets at least 5000 Å in extent, manifestly smooth. This facetting transition is completely reversible. This is the first observation of this extraordinary surface phenomenon.

The discovery of high-temperature (high $-T_c$) superconductivity has created enormous excitement in both the scientific and popular communities. At the beginning of 1987 most solid-state physicists believed that, as for the conventional variety, superconductivity in the copper oxides was caused by the interaction between electronic and ionic excitations (electron-phonon coupling). However, in the summer of 1987, neutron-scattering experiments carried out in collaboration among MIT, Brookhaven, NTT and Tohoku University showed that the new materials contain rapidly fluctuating antiferromagnetically correlated magnetic moments on the Cu ions. Since magnetism and conventional superconductivity do not coexist, this caused a radical change in the prevailing view and the majority now believe that the magnetism is the source of high- T_c superconductivity. Subsequent neutron work showed that the addition of charge carriers (holes) drastically reduces the length scale over which the holes are antiferromagnetically correlated. Measurements at the Francis Bitter National Magnet Lab showed, in addition, that the charge carriers are highly sensitive to the magnetic order of the Cu spins. Since two holes disrupt the antiferromagnetism less, and therefore cost less energy if they are close together than if they are far apart, the pairing of holes necessary for superconductivity can be understood in a simple way. This led to the successful prediction of the dependence of the superconducting transition temperature T_c on hole concentration. Since the temperature scale in this model is ultimately limited by the antiferromagnetic exchange energy (~ 2600 K) there is no reason to believe that room temperature superconductivity is unattainable.

Successful thin film synthesis and material characterization of nearly single-phase thin films of $\text{YBa}_2\text{Cu}_3\text{O}_{7-x}$ and $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_{8+x}$ have been carried out. The 2D-3D dimensionality crossover in thin films of $\text{YBa}_2\text{Cu}_3\text{O}_{7-x}$ has been observed. In addition, the critical currents have been measured as a function of magnetic field strength and orientation in thin films of $\text{YBa}_2\text{Cu}_3\text{O}_{7-x}$. At 77 K critical currents of more than 10^5 amps/cm² in a parallel field of 15 Tesla are observed. From such data (at 77 K) one infers a pinning strength in this material, and observes scaling that is in agreement with the existence of a vortex lattice with the expected shear modulus. Such scaling allows one to infer the parallel critical field of this material, which is in excess of 60 Tesla at 77 K.

In a collaborative effort between Physics and EECS, semiconductor devices have been fabricated that are so small (~30 nm) that new quantum mechanical effects can be observed in the electronic conductivity. In measurements of the conductance G of Si field-effect transistors of width $w=300-100$ nm and $2-10$ μm long in high magnetic fields ($B=8-23$ T) new behavior was discovered which suggests that electron-electron interactions are altered in this confined geometry. At a threshold magnetic field (~4T for $w \sim 100$ nm) G increases with H by as much as a factor 10. Above this threshold, G depends in a peculiar way on carrier density, proportional to the gate voltage: G rises with gate voltage in a series of steps each of order $2 e^2/h$. The risers of these steps shift to higher gate voltage linearly in B , suggesting that they occur at fixed filling factor, the ratio of electron density to flux-quantum density. Each plateau disappears at a different temperature revealing a family of phase transitions, one for each plateau. While this behavior is similar, in some respects, to that of the quantum Hall state, the shape of the plateaus, the size of the steps, and other features cannot be explained without new many-body effects.

During the past year it has been possible to relate the phase separation characteristics of individual lens proteins to the specific amino acid sequence of these proteins. These results clearly indicate a systematic method by which natural and synthetic modifications of the proteins at selected sites should be capable of producing or inhibiting cataract *in vivo*.

3. Plasma Physics

Very short period microwigglers for free electron laser applications are of much current interest. Besides their compactness such systems have the advantage of producing high 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 in the manufacture of multichannel magnetic recording heads for space borne applications.

In addition to the above work, the physics of prebunching in a free electron laser has been studied; this is 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 our experiments has been confirmed by computer simulations.

The possibility of constructing experiments, using existing technology and physics knowledge, in order to attain conditions where a fusing plasma mixture can ignite was first demonstrated at MIT in 1975 and investigated thereafter. In fact, the MIT group has produced a series of design studies on compact ignition devices which incorporate the main features of the Alcator series of experiments. These studies have led to the undertaking of the first theoretical investigations of the basic physical properties of fusion burning plasmas. During this past year the line of compact ignition experiments proposed at MIT have attracted large scale activities and considerable funding in the United States, Europe, and in the Soviet Union.

At MIT, the Alcator-C MOD device is under construction. This is based on a concept (Megator) proposed at MIT in the early 1970's and combining the favorable confinement characteristics of the Alcator line of experiments with those of plasma equilibrium configurations having properly elongated cross-sections of the plasma column. The combination of all these characteristics was in fact shown to allow stable plasma currents in the multiple megampere range.

A new experimental program has now been officially proposed at MIT, to investigate the properties of the so-called "Second Stability Region" as identified and studied by us in 1978-1980. This program, entitled Versator-MOD, has been favorably rated by the US Department of Energy.

The development of tera-electron volt electron-positron colliders presents numerous physics and engineering challenges. Among the most promising new collider concepts are those that use high gradient, high frequency slow wave structures which are powered by new coherent radiation sources. The non-linear physics of two sources, the free electron laser and the cyclotron resonance maser have been investigated; and there is good agreement between our theory and free electron laser experiments. Cyclotron resonance maser experiments are being planned. The requirements of high luminosity, low-energy, colliders have been examined. We have presented parameters for both B - \bar{B} factories and 1TeV x 1TeV colliders.

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. Analysis of the data taken on the three-nucleon "mirror" nuclei is in its final stages. A conclusion recently drawn from those data is that microscopic calculations successfully reproduce the ground-state correlations in these nuclei but fail to reproduce the time-dependent response. Another difficult experiment, this one examining the polarization observables in electron scattering from deuterium, is nearing completion and 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 will demand the development of entirely new experimental capabilities (e.g. out-of-plane magnetic spectrometers) and are characteristic of the types of program which will be central to research using the South Hall Ring now under construction.

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 in the so-called dip region intermediate to the quasifree elastic and the delta-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 the quasi elastic regime no dependence on momentum transfer is observed between 2 and 5fm^{-1} over that expected from free nucleons. This is an indication that anomalies in the Coulomb sum rule and the transverse/longitudinal ratio of inclusive electron scattering are not likely to be represented by a simple modification of nucleon structure such as an increase in radius. The transverse and longitudinal behavior of the $^{12}\text{C}(e,e'p)$ reaction has also been measured. For the 1p-shell, the results are in agreement with the behavior expected on the basis of quasielastic knockout. However, the 1s-shell is strongly enhanced in the transverse mode. The transverse spectral function also extends to much higher excitation energies in the residual system than the longitudinal. It appears that a new current is being observed with the more deeply bound shell that augments the quasi elastic knockout process in the transverse mode.

c. 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 SIN. Along with collaborators from other institutions, the MIT group is building 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.

d. South Hall Ring

The Bates research program has done much to frame the questions and to establish the experimental basis for the future electronuclear studies needed to advance nuclear physics along new directions. The new capabilities needed have been identified: continuous (CW) beams and full utilization of polarization observables. The South Hall Ring (SHR) project at the Bates Laboratory is an experimental initiative which will provide these capabilities throughout the important energy range accessible to the existing accelerator (i.e., up to 1 GeV). The South Hall Ring will be available for research in 1992. It will be an integral part of the South Experimental Hall using existing beam lines for experiments in the internal target mode and in the extracted beam mode. This is accomplished by using the SHR to manipulate the time-structure of the pulsed beam provided by the accelerator. Many of the needed detectors and the polarized beam are available.

In the internal target mode, the electrons are circulated thousands of times through a windowless gas target introduced into the ring. The major benefit of this configuration is that it permits (and requires) the use of exceedingly thin targets, i.e., targets so thin that an insufficient number of interesting collisions would take place if each electron passed through the target only once. There are several advantages to this approach. One is that heavily ionizing reaction products are able to leave the target and reach the detector. This possibility is central to a number of planned experiments, for example, those aimed at a basic understanding of nuclear fission or of the propagation of pions in the nuclear interior. Perhaps the most exciting prospect, however, is that associated with polarization. Advances in laser technology and surface science now make it feasible to produce gases of polarized nuclei of sufficient thickness for internal target use. There is considerable activity in this field, for example, at Argonne, Caltech, Harvard, Indiana, MIT, Oak Ridge, Princeton, and Wisconsin. Such internal target experiments, representing a significant departure from the traditional experimental configuration in electronuclear physics, will require innovative developments advancing both physics and technology. In considering potential developments at Bates, the Nuclear Science Advisory Committee has stressed that the "combination of internal target capability and polarized beams for addressing important new areas...will be unique in the world."

In the extracted beam mode, the SHR will be used as a pulse stretcher. The basic idea is that the SHR will capture each accelerator beam pulse and then "leak" the electrons to the experiment uniformly between pulses. The technical challenge lies in performing the filling and emptying procedures efficiently, rapidly, and yet smoothly. We anticipate a broad program, for example, in exploring nuclear collective motion, in mapping the nuclear spectral function, and in measuring the nuclear pion distribution near threshold. With the South Hall Ring experimental initiative at Bates and the major new facility at CEBAF, the American basic research community will have at its disposal unmatched capabilities built upon novel technologies.

2. Relativistic Heavy Ions

The Heavy-ion Group is a large part of the E802 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, were hoped to 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 algorithms) 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 π^+ 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 (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 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. They have completed the final experimental run in this program and are now analyzing the data.

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 being analyzed. (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 and study heavy quarks 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 just beginning to function.

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 are also a large number of charmed mesons available for study.

d. Electromagnetic Interactions (EMI) Group. The EMI Group is building a large precision detector at the 200 GeV electron-positron accelerator, LEP, in Geneva, which is to begin operating in 1989. The Group has been leading this large construction effort, which involves 350 PhD 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 sixth quark, and to probe beyond the standard theoretical models. The precision electron, muon, and photon detectors developed for this experiment also serve as prototype 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⁺ 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 UA1 Uranium-Tetramethylpentane Calorimeter. In particular, this group is in charge of the design and construction of the Position Detector for the new calorimeter. This state-of-the-art calorimeter has possible applications for future detectors at SSC.

Theoretical Division

1. Particle Theory

The "standard theories" of the interaction of quarks and leptons through gauge fields are quantum chromodynamics (QCD) for the strong interactions, the W-S-G theory for the electromagnetic and weak interactions and general relativity for gravitational interactions. They are powerful and in complete agreement with experiment, but they contain no answers to the fundamental question, why this particular hierarchy of particles and interactions? The theory of super-strings endeavors to unite all physics at the Planck scale, where quantum effects in gravitation start to dominate. Since this scale is totally inaccessible to experiment, this theory makes great use of internal consistency requirements. Through we know a beautiful formulation of the theory as an infinite series of terms corresponding to increasingly topologically complex surfaces, we do not have a field theory of superstrings on the model of the standard theories. A major continuing effort of members of the Particle Theory Group has been to construct such a theory, using a combination of algebraic and geometrical techniques.

As a test of our understanding of quantum gravity, members of the Group have studied whether it is in principle possible to create a whole new inflationary universe "in the laboratory", i.e., out of a concentration of energy in a small region. Applications of ideas from particle physics to cosmology have been an important area of research. The various kinds of topological defects which exist in many field theories could have an essential part in the development of our universe; in particular cosmic vortex-strings could be associated with galaxy formation. Members of the Group have been studying this problem by both analytic and numerical methods. Many of these astrophysical and cosmological studies concern quantum field theory applied to systems not in thermal equilibrium. Members of the Group have developed variational techniques for dealing with such situations.

Much of the Group's work on the application of the standard theories has been concerned with the question of reconciling with the basic theories useful models that describe the phenomena more or less directly. Members of the Group have studied what recent experiments tell us about the strange quark content of the proton and suggest further measurements; they analyze the apparent contradiction between these measurements and the simple quark models that describe the baryons so well. They are investigating whether the model of the baryon as a soliton of an effective meson theory in fact contains more information about the quark degrees of freedom than has been thought. An example of the kind of standard theory analysis that can be done in anticipation of experiments at higher energies is the reexamination of what we know about the possible mass of the Higgs boson. If there are sufficiently massive quarks or leptons, the standard theory Higgs boson could be very light. Analysis of the decays of K and B mesons has placed a lower limit on the Higgs mass.

2. Nuclear Theory

The MIT Nuclear Theory Group addresses a broad range of problems in contemporary nuclear physics. The research program combines new initiatives in emerging fields with active ongoing efforts in areas in which MIT has traditionally played a leading role.

Theoretical research continues to benefit from strong interactions with experimentalists in electromagnetic and relativistic heavy ion physics and contributes significantly to these experimental programs.

Hadronic 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 confinement are exploring the role of color deformed states, chromomagnetic monopoles, the quantum mechanics of a multiply connected space, the ground state wave functional of pure Yang-Mills theory, and classical Yang-Mills solutions. The general theoretical problem of how to formulate effective operators in hadronic degrees of freedom relevant to conventional low energy nuclear physics is being studied in the context of a non-relativistic confining quark model. The bag model, which economically enforces the confinement aspects of QCD, is being used to explore the possibility of observing multi-quark resonances in hadron scattering. A complementary description motivated by the large N limit of QCD, in which the only relevant degrees of freedom are meson fields, is being explored by studies of chiral and Skyrme models.

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 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 the J/ψ production could reflect screening in the quark gluon plasma, such suppression was observed in the CERN experiments. Hence, particular theoretical effort has been devoted to the quantitative study of charm production and possible compensating processes.

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, and recent efforts have focussed on understanding the nature of periodic solutions to multidimensional classical systems and field theories and calculating periodic solutions for physical processes. Stochastic solution of many-body problems has proven valuable in a variety of applications, in addition to lattice gauge theory, ranging from the exact solution of non-relativistic models with static two-body interactions to calculation of the thermodynamic properties of quantum spin systems. An example of the strong interplay between many-body theory and field theory is the recent exploitation of the analogy between "deformed" gluon states in QCD and deformed nuclei.

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. Much of the current work addresses coincidence experiments, ranging from fundamental studies of the reaction mechanism in proton knockout experiments, to explanations of how spin observables in coincidence experiments can be exploited to reveal new features of nuclear structure. 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, study of isospin mixing in parity violation experiments, and investigation of a new phase of QED relevant to the anomalous positron peaks in heavy ion collisions. Activities in intermediate energy physics also include the study of the pion optical potential, pion nucleus scattering, and pion production.

JEROME I. FRIEDMAN

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 principal source for funding the Center is the National Institutes of Health (NIH). The Center is headed by Professor Phillip A. Sharp, Principal Investigator, and Donald J. Giard, Director. 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 working directly with individual scientists on basic research problems and, in addition, is conducting an active program in the development of new technology for large scale animal cell production.

During this reporting period, the activities of the Center were highlighted at the annual meeting of the National Advisory Research Resources Council, NIH, Bethesda, Maryland. A presentation was made by Donald Giard, explaining the Cell Culture Center operation. This was followed with a presentation by Dr. Timothy Springer (Dana Farber Cancer Institute) describing his research as one example of many research projects throughout the United States, made possible by the services provided by the Center.

During the period July 1, 1987 to June 30, 1988, 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 cultures and microcarrier cultures. More than 10^{13} cells were produced as the demand for cells continued to increase. Examples of projects completed during the past year include:

- . 158 liters per month of human lymphoblastoid cells for Harvard University, Cambridge, Massachusetts; for studies which recently led to determination of the structure of the human class I histocompatibility antigen, HLA-A2.
- . 40 liters per month of HeLa cells for The Salk Institute, San Diego, California; for isolation and sequencing of CREB protein.
- . 100 liters of HeLa cells for Johns Hopkins University, Baltimore, Maryland; for purification of DNA replication factors.
- . 280 liters of lymphoblastoid cells for MIT, Cambridge, Massachusetts; for the study of antigen recognition by clones of T-lymphocytes.
- . 60 liters of conditioned medium from TCC cells for Massachusetts General Hospital, Boston, Massachusetts; for purification of bone resorbing factor.
- . 200 liters of K562 cells for the University of Michigan Medical Center, Ann Arbor, Michigan; for the studies on nuclear factors involved in regulation of expression of the human hemoglobin genes.
- . 12 liters of rat endothelial cells in microcarrier culture for MIT, Cambridge, Massachusetts; for purification and characterization of heparin sulfate proteoglycans.

Research on cell attachment factors has resulted in the development of a cell attachment assay which can be used to measure the relative amounts of attachment activity present in various serum batches. This assay also has the potential for differentiating between different cell types based upon their degree of dependency on serum attachment factors. Another area of research has centered on finding ways to reduce our dependency on fetal bovine serum. Media formulations have been developed which allow reduction of serum concentration by up to 80 percent on cell lines thus far tested.

MIT recently made the decision, based upon changing priorities with regard to space utilization, not to continue to provide space for the Cell Culture Center to operate. The Center will therefore officially cease to operate at the end of its current NIH grant period, March 31, 1990. Until that time, the Center will attempt to maintain its staff and continue to provide its services to researchers throughout the United States. Officials at NIH have indicated their intention of continuing to support 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. Research programs in three major areas, immunology, cell biology and oncogenes and mammalian genetics, are being actively pursued by 11 faculty members and their laboratories. The Center is currently the research home of 155 people including faculty, postdoctoral fellows, visiting scientists, and graduate and undergraduate students.

An excellent cellular immunologist, Dr. Harald von Boehmer, currently of the Hoffman-La Roche Immunology Institute in Basel, Switzerland, has accepted the position of Professor of Immunology in the Department of Biology. His laboratory will be housed in the Center in the space next to the laboratories of Drs. Nancy Hopkins and Susumu Tonegawa, and his research will further strengthen our superb immunology group. Dr. von Boehmer is interested in the mechanism by which the immune system of animals distinguishes between self and non-self. This is thought to be controlled by a subset of immune cells, the T cells, which are "educated" during development in the thymus of the animal. The human immune system is thought to be important in controlling and potentially killing newly emerging malignant cells. Dr. von Boehmer's research in the Center will complement that of other faculty members, specifically, Drs. Herman Eisen, Susumu Tonegawa and David Raullet, in elucidation of how the potent reactivity of the immune system is specified and controlled.

The other change in academic appointments in the Center was the promotion of Dr. H. Earl Ruley to Associate Professor in the Department of Biology. Dr. Ruley has made critical contributions to the mechanism by which two different oncogenes collaborate in producing a cancer cell.

The most exciting event during the past year was Dr. Tonegawa's reception of the 1987 Nobel Prize in Physiology or Medicine. This was preceded by the 1987 Albert and Mary Lasker Award. Dr. Tonegawa was honored for his discovery that the genes encoding the recognition proteins of immune cells are assembled in developing cells by highly specific rearrangements of subgene segments. This insight provided an explanation for how the immune system of an animal develops recognition molecules for millions of different foreign pathogens and chemicals.

A number of other faculty members in the Center were also recognized for the excellence of their research and teaching activities. Dr. Frank Solomon received the Graduate Teaching Award for his commitment to graduate education. Drs. Brent Cochran and Phillip A. Sharp were appointed to the Pfizer Career Development and the John D. MacArthur professorships, respectively. The sustained importance of Dr. David Housman's research program was acknowledged by a National Institutes of Health Merit Award.

The agreement between the Howard Hughes Medical Institute (HHMI) and MIT, which resulted in a \$15 million contribution to the construction of a new building for the Department of Biology also benefited the Center. Two of the three scientists initially selected to join HHMI as Investigators are faculty of the Center, Dr. Richard Hynes and Dr. Tonegawa. Their selection was based on a national competition and the support will permit an expansion of their research programs. In addition, the Center is providing space in establishing research support facilities for cell sorting and microchemical analysis of biological molecules with HHMI support.

There have been several important advances in research in the Center during the past year. Several years ago, Dr. Tonegawa's laboratory isolated a novel gene (γ) from a T cell that was proposed to encode a cell surface receptor for recognition of antigens. This discovery stimulated others to search for another type of gene in T cells that would specify a protein which would join γ in forming a complete cell surface recognition receptor. This type of receptor gene is now referred to as δ . Recent studies in Dr. Tonegawa's laboratory and that of others suggest that T cells, in a unique part of the immune system, express both γ and δ receptors. These T cells are confined to the epithelium of mammals where they might be important in controlling infections and perhaps monitoring for newly formed cancer cells.

Another important advance in research in the Center also involves cell surface recognition proteins. Most of the cells in the human body maintain their appropriate position by recognition of an intercellular matrix formed by a secreted large protein called fibronectin. Several years ago, Dr. Hynes discovered that tumor cells did not bind this fibronectin matrix with as high an affinity as normal cells. Guessing that receptors on the cell surface are critical for this binding, he began an analysis of cell surface proteins that recognized

fibronectin. Interestingly, his laboratory has recently shown that a class of cell surface receptors for fibronectin is lost as a normal cell is transformed into a malignant cell. Future research will show if this change is critical in permitting tumor cells to migrate and invade adjacent tissue.

The strength of the Center remains its attractiveness as an environment for the training of young scientists. The Center currently has 37 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: Professors Harald von Boehmer of the Hoffman-La Roche Immunology Institute in Basel, Switzerland, Charles Janeway of Yale Medical School, Judy Lieberman of Tufts New England Medical Center, and Minou Bina of Purdue University. During the past year, the Center served as the training ground to a number of medical fellows from different hospitals outside (West German Cancer Center, West Germany, Osaki Teishin Hospital, Osaka, Japan, and Hospital Universaterio del Valle, Columbia, South America) and in the Boston area (Harvard Medical School, New England Deaconess Hospital, Beth Israel Hospital, and Massachusetts General Hospital).

PHILLIP A. SHARP

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, 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 initiated this year 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 McGraw-Hill 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 has recently become available for foreign guest usage. Thus, cosmic X-ray phenomena can now be studied not only by using data from the archives of past US and European missions but also by competing for observing time on foreign spacecraft. The MIT X-ray group has charge of several of the US archives with ready access to the others, and has been successful in obtaining observing time on GINGA, thus remaining active in the field while preparing for the next generation of space missions to be launched by the US in the 1990's.

Professor Hale Bradt and Dr. Ronald Remillard are tracking down and identifying by optical observation the X-ray sources whose positions were measured with high precision in past spacecraft flights. Professor Claude Canizares and his associates have continued their studies of X-ray emission from supernova remnants, galaxies, clusters of galaxies, and quasars, using archival data from the Einstein Observatory and new observations made at the McGraw-Hill 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). Recently Professor Lewin and his coworkers have also made observations using GINGA 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 students, working in collaboration with Dr. Fumiaki Nagase of the Institute of Space and Aeronautical Sciences (ISAS) in Tokyo, is studying the atmospheric structure of the primary stars of eclipsing X-ray binaries using GINGA data to observe the gradual decrease in emission from X-ray secondary stars during their occultation by the primaries. Working with Dr. Remillard, Professor Clark is also using archival SAS-3 data in an attempt to understand the soft X-ray transient phenomena observed in A0620-00 in 1975, a source that appears from optical studies to be a black hole.

Advanced X-ray Astrophysics Facility (AXAF). A team under Professor Canizares has continued the definition study of new instrumentation for the High-Resolution Spectroscopy Investigation on AXAF. Submicron X-ray transmission gratings (fabricated in collaboration with Professor Henry I. Smith, EECS) have been made and tested at energies up to 8 keV. Preliminary engineering designs have been completed for both the X-ray transmission grating and the Bragg crystal spectrometers. A proposal for the development phase is being prepared for NASA's approval.

During the past year, the AXAF Charge-Coupled Device (CCD) Imaging Spectrometer experiment (MIT's second AXAF entry) entered the detailed design and definition phase under the leadership of Dr. George Ricker 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 recently furnished prototype versions of the high-resistivity sensors which are being evaluated at CSR over a broad range of X-ray energies.

ASTRO-D Mission. This program is a newly-initiated 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 the launch 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.

X-ray Timing Explorer (XTE). This effort represents a relatively inexpensive NASA X-ray astronomy satellite program that is scheduled for launch in the mid-1990's 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.

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. Recently, NASA adopted HETE as a "new start" in FY 1990, leading to an expected launch in FY 1992/1993. 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 novel 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, and CNES/CESR (Toulouse, France).

McGraw-Hill Observatory. The McGraw-Hill Observatory, located on Kitt Peak near Tucson, Arizona, is operated jointly by MIT (CSR), the University of Michigan, and Dartmouth College. The new 2.4-m-dia instrument is now fully operational, although the primary mirror is still being evaluated for possible further improvement in its imaging quality. A new CCD imaging camera has been constructed at CSR and operated successfully on the telescope. Prime-quality "dark time" on this instrument is currently heavily oversubscribed by MIT and other observers.

Some highlights of work carried out at the McGraw-Hill facility last year include: the discovery by Professor Bradt and Dr. Remillard of X-ray-luminous quasars and new types of cataclysmic variables; searches by Drs. Ricker and Roland Vanderspek for optical counterparts to the gamma-ray bursters; observations of comets and asteroids by Professors David Jewitt (EAPS) and Jack Wisdom (EAPS); observations of galaxies and galactic clusters by Professors Canizares, Clark and Tonry; measurements of the structures of planetary rings by Professor James Elliot (EAPS) and Dr. Edward Dunham; and searches for optical counterparts to radio sources by Professor Bernard Burke.

Explosive Transient Camera (ETC). This facility, colocated with the McGraw-Hill Observatory on Kitt Peak, is designed to search the entire night sky for, and detect, 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 1988. 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, in August 1989), the group is heavily involved in intensive planning for both the 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 is beginning 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 instrument, when launched, 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.

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, 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.

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, is planned for launch in April of 1989. 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.

SPACE GEODESY

The space geodesy group, led by Professor Charles Counselman (EAPS) has developed a way of monitoring strain in the earth's crust using portable apparatus that receives radio signals from existing satellites. An improved method of determining the orbits of these satellites, developed and tested by the group this past year, has reduced the uncertainties in measuring crustal strain to several parts in a hundred million.

RADIO ASTRONOMY

Very-Large-Array and Very-Long-Baseline-Interferometer (VLBI) Observations. Professor Bernard Burke and his associates, in collaboration with colleagues from Princeton and the California Institute of Technology (CIT), have continued to search for and find a number of radio sources that appear to have been modified by intervening masses acting as gravitational lenses.

Professor Burke continues as PI of the US team participating in the European project to establish a VLBI station in Earth orbit (known as QUASAT), now envisaged for realization 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 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). A major decision was made in September, 1987, to build a Fabry-Perot, rather than a Michelson, interferometer, as the first detector to be installed in the full-scale implementation; a second decision was taken in March, 1988, to concentrate design efforts on the use of a 0.5- μm laser wavelength, rather than 1.0 μm .

The Project goal is to have 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 bringing a new 5-m prototype antenna into operation this year, development of optical techniques to make the Fabry-Perot system viable, development of suspension and ground-noise isolation techniques to extend the sensitivity of the detector to frequencies below 1 kHz, and development of efficient and quiet solid-state lasers. A substantial portion of the MIT group's current effort is going into the conceptual design and engineering of the full-scale LIGO facilities.

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 search for large-scale anisotropies in the natural cosmic background radiation 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 on a Delta expendable rocket in 1989) 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.

Non-linear Dynamics. Dr. Paul Linsay continues his research in non-linear dynamics under a three-year grant from the Office of Naval Research. Studies have been directed towards understanding the transition, undergone in some non-linear electronic systems, from quasi-periodicity (i.e. simultaneous oscillations at several non-harmonic frequencies) to chaos. His group has succeeded in constructing several circuits that demonstrate these transitions, as well as in defining their basic operating domains.

AEROSPACE PHYSIOLOGY AND MAN-MACHINE SYSTEMS

Experiments on human adaptation to weightlessness continue in the Man Vehicle Laboratory (MVL), under the direction of Dr. Charles Oman, who is serving as Acting Director of the Laboratory during Professor Laurence Young's (AA) sabbatical absence in academic year 1987/1988. The research focusses on how weightlessness affects the visual-vestibular function, spatial orientation, and flight-simulation posture control, and on how it causes space motion sickness. Disorientation and motion sickness are recognized as the most important operational medical problems now faced in short-duration space missions. The hiatus in flight activity resulting from the Challenger accident has provided a useful opportunity for data analysis and modification of hardware and crew procedures prior to the third mission in the Spacelab (SLS) series: SLS-1, now scheduled for 1990. Experiment proposals by Dr. Oman and Professor Young have been selected for flight on subsequent missions in the SLS series. Professor Steven Bussolari is responsible for the Mental Workload and Performance Experiment, and Dr. Oman for a portion of the Microgravity Vestibular Investigation, both currently planned for Spacelab IML-1.

A vigorous program of ground-based research includes studies of the visual-vestibular interaction using the MVL linear acceleration sled; a "telescience" experiment, jointly with colleagues at several NASA centers, aimed at defining voice, video, and data communications required for the Space Station; studies of physiologic changes that accompany the onset of motion sickness; and information processing in the cockpits of highly automated transport aircraft. Professor Steven Bussolari directed the flight operations and exercise physiology research of the Daedalus Project, which successfully flew an MIT-built human-powered aircraft from Crete to the island of Santorini in the spring of this year. While on sabbatical leave at Stanford University, Professor Young has explored the potential for expert-systems software technology in the support of astronaut flight crews and ground-based scientists as they perform experiments on the Shuttle and Space Station.

GORDON H. PETTENGILL

Experimental Study Group

The Experimental Study Group (ESG) finished its nineteenth year of providing an alternative academic education for MIT undergraduates. Its educational philosophy has continued to focus on combining flexibility in curriculum and pedagogy in the core freshman subjects within a strong community atmosphere, a combination which remains as popular today as it was almost twenty years ago when ESG began.

STUDENT STATISTICS

ESG enrolled 50 new freshmen, 6 sophomore transfer students, and 25 ESG upperclassmen for one or more terms this year. Thirty-six percent of the first year students were women, 7 percent were minority students, and 39 percent were international students. Approximately 25 percent of all incoming international students at MIT enrolled in ESG this year, an extraordinarily high percentage even for ESG. These students represented nineteen different countries from five continents, including countries as diverse as Zimbabwe, France, and Colombia. They listed the small classes available at ESG and the opportunity for self-paced study as the main reasons why they joined ESG. In the words of one freshman from Singapore: "I joined ESG because its flexibility allows me to study at my own pace. I've received advanced credit for some courses and have had exposure to some others. ESG allows me to skim through things I already know and concentrate on new topics or go deeper in a particular area. ESG has small group tutorials, a system of education I am more comfortable with. ESG is also a community where friends can be made and experiences, both academic and non-academic, may be shared."

The 42 sophomores currently registered at MIT who had been in ESG as freshmen achieved a median grade point of 4.4. This figure is higher than the corresponding figure for the entire MIT sophomore class for the seventh consecutive year. Forty-seven percent of our sophomores are majoring in the School of Engineering, 40 percent in the School of Science, 9 percent in the School of Humanities and Social Science, 2 percent in the School of Management, and 2 percent in the School of Architecture and Urban Planning. Sixteen of our 42 sophomores took one or more subjects in ESG, mostly in mathematics and the humanities. The most common reason given by sophomores for taking a subject in ESG rather than the regular curriculum was the opportunity to proceed at one's own pace and to participate in one-on-one tutoring.

STAFF AND FACULTY

Professor J. Kim 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 composed of faculty representatives from the Departments of Mathematics (Professor David Anick), Physics (Professor Lee Grodzins), Chemistry (Professor Alan Davison), Humanities (Professor Arthur Kaledin), and the Dean of the School of Science, Professor Gene Brown. Along with their administrative roles at ESG, Professor Vandiver also taught in the Department of Ocean Engineering, and Ms. Sweet continued her appointment as Lecturer in the School of Science.

The mathematics staff at ESG consisted of Dr. Richard Montgomery, a Moore instructor in the Department of Mathematics at MIT, and mathematics graduate students David Gillman and Harold Sadofsky. The physics staff included Professor John King, Professor Emeritus Robert Halfman, Dr. Peter Dourmashkin, Craig Watkins, and graduate student James Mahoney. The humanities staff for the year included Lecturers Fanny Howe (Writing) and Ms. Sweet (Psychology), graduate student Lee Perlman (Political Science), and ESG alumnus David Custer '82 (Writing). Almost half of our first year students took at least one humanities subject in ESG this year.

The chemistry staff was composed of two ESG undergraduates, Seth Brown '88 and Marya Lieberman '89, who taught 5.11 Principles of Chemical Science exclusively through ESG for the first time. An extensive chemistry text for 5.11 was developed by a team of three ESG undergraduates during the previous summer and was utilized by our 5.11 students during the fall term. Ms. Lieberman was also responsible for teaching an ESG recitation section of 5.12 Organic Chemistry in the spring term. We are very pleased to announce that Mr. Brown won a 1988 Compton award, based in part on his commitment to teaching chemistry and advising students at ESG over the past three years.

Thirty-three ESG freshmen and upperclassmen assisted the ESG staff in tutoring students this year, primarily in the introductory math, physics, and chemistry subjects. Our tutors not only did a superior job teaching their students but also excelled academically, earning a median grade point of 4.6. The extensive support of our tutors has enabled us to maintain the highly favorable student to staff ratio which has been a hallmark of ESG's personalized approach to education over the years.

ACADEMIC DEVELOPMENTS

The staff at ESG continue to be involved in activities in the MIT community outside of ESG. A third of ESG's staff members taught subjects in the first session of Interphase last summer. Professor Vandiver was a member of the Faculty Policy Committee for the third year in a row. Ms. Sweet participated for a second year in interviewing freshmen for Professor Benson Snyder's Freshman Interview Project.

ESG sponsored two different academic activities for credit during the Independent Activities Period (IAP): Physics of the Bicycle Wheel (taught by Dr. Dourmashkin and Mr. Watkins) and Writing Workshop (a new subject for credit taught by Fanny Howe). We are pleased to announce that Ms. Howe won an IAP Excellence award for her work in developing this innovative and highly successful IAP activity. We will be investigating additional ways of encouraging freshmen to pursue hands-on experience for credit during the coming IAP period.

In response to the changing educational needs of the entering freshman classes at MIT over the past few years, ESG has begun to develop a greater variety of approaches to introductory math and physics subjects, including a broadening of self-paced texts available in math and physics, and the creation of a pre-calculus subject which would allow students without a firm calculus background to prepare more adequately for freshman math and physics at MIT. We believe that our small size and interactive student-staff format make ESG an ideal place to pursue such experiments in the future.

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, micro-computers 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, Chemical Engineering, Mechanical Engineering and Applied Biological Sciences. There were also numerous collaborations with outside academic institutions, many of an interdisciplinary nature, as well as with government, industrial and medical organizations.

This past year was one of continued growth. A new picosecond laser facility is operational. Picosecond laser pulses in the UV/visible region combined with single photon counting detection system measure fluorescence lifetimes. The Laser Biophysics Laboratory is now equipped with absorption and fluorescence spectrophotometers for routine analysis of materials, including biological tissue.

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 eighth 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 third 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 are being 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 and Drs. Paul L. Skipper and Liang-Shang Gan, all of the Department of Applied Biological Sciences, continue their studies on the fluorescence quantitation of carcinogen bound protein and DNA adducts in collaboration with Drs. Ramachandra R. Dasari, Michael S. Otteson, and Mark M. Doxtader of the Spectroscopy Laboratory. Experiments have studied the direct measurements of intact aflatoxin B₁ serum albumin adducts. A 0.5-1 pmole aflatoxin B₁ per mg of albumin detection limit has been achieved with SPEX fluorimeter and pulsed Nd:YAG pumped DCM dye laser. A significant correlation of aflatoxin B₁ adduct level with daily aflatoxin B₁ intake was observed in a molecular epidemiological study. They have also begun the studies on the quantitation of benzo[a]pyrene globin peptide adducts and have achieved detection limits of 17 picomolar with conventional synchronous fluorescence spectroscopy and 10 picomolar with Nd:YAG pumped LDS 698 dye laser. Current studies are focused on further increasing the detection sensitivity by low temperature synchronous fluorescence scan and fluorescence line narrowing techniques as well as time-resolved laser induced fluorescence.

Professor Jeffrey I. Steinfeld of the Department of Chemistry is investigating the use of two-photon pumping for the preparation of electronically excited states of nitric oxide molecules for subsequent Stimulated-Emission Pumping experiments, designed to elucidate relaxation dynamics in highly vibrationally excited states. Preliminary experiments using an etalon-narrowed excimer-pumped dye laser have indicated that a significant fraction of the ground-state molecules could be pumped with pulse energies in the 8 to 10 mJ range. Fluorescence dip measurements have been made which indicate that the two-photon excited molecules can be efficiently transferred to high v'' levels of the X state.

Professors Robert W. Field and Robert J. Silbey, also 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 S₁ 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-Double Resonance (ODR) Spectroscopy. ODR 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 $\text{Ca}^+ \text{O}^-$) 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 Stephen J. Lippard, of the Department of Chemistry, is studying the Raman special features associated with oxo-bridged polyiron moieties in biology. Characterization of $\{\text{Fe}_2\text{O}\}^{4+}$, $\{\text{Fe}_4\text{O}_4\}^{8+}$, and $\{\text{Fe}_2\text{O}_2-(\text{OH})_2\}^{12+}$ cores in newly synthesized biologically relevant model complexes is continuing. In addition, Dr. James Bentsen, also of the Department of Chemistry, is making use of newly acquired Ar^+ and Kr^+ lasers for the low temperature investigation of a binuclear iron center in the protein methane monooxygenase. In collaboration with Prof. JoAnne Stubbe of the Department of Chemistry, Raman spectroscopy is being used to study the mechanism of $\{\text{Fe}_2\text{O}\}^{4+}$ core formation during reconstitution of protein B2 of the protein ribonucleotide reductase from *Escherichia coli*.

Professor Alexander Rich and Drs. Andrew H.J. Wang and Gary Quigley, all of the Department of Biology, are studying the anthracycline drug closely related antibiotics daunomycin and adriamycin for use in treating human carcinomas. They have also studied the quinoxaline antibiotics echinomycin and triostin A, which are also anti-tumor agents. In an attempt to understand how DNA interacts with these drugs, they have been co-crystallized with various fragments of DNA of different lengths. The crystal structure of several drug complexes has been solved. The complexes with the quinoxaline antibiotics revealed an unusual conformational change with the introduction of novel hydrogen bonding interaction between the DNA bases. A number of chemically similar compounds have also been either isolated or synthesized, and the effects of specific chemical substitutions in these drugs have been correlated with biological activity.

Dr. Robert J. McMahon, also of the Chemistry Department, and Visiting Scientist Ken Force, Professor of Chemistry at the University of Rhode Island, have been working on the properties of a new molecule consisting of a viologen moiety covalently linked to a porphyrin derivative. The porphyrin is the light absorber and the viologen a primary electron acceptor, and Raman spectroscopy is being used to establish the nature of the events following photoexcitation of the porphyrin center. In another set of experiments with multicomponent redox molecules, Professor Wrighton and his collaborators are working to establish factors influencing the nature of excited state electron transfer to surface-confined viologen oligomers and other multi-component molecules. Transient Raman spectroscopy has been used to establish that high surface area SiO_2 modified with viologen oligomers will accept electrons from photoexcited $\text{Ru}(2,2' \text{bipyridine})_3^{2+}$ in solution.

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 DMSE, 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 nickel-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 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.

Professor Toyochi Tanaka and Dr. Sridhar Gorti are using the technique of dynamic light scattering spectroscopy under microscope, which allows observation of macromolecular Brownian motions within single cells. They carried out studies on three different subjects. (1) The eye lens tissue contains two cell types: epithelial cells and fiber cells. The epithelial cells within the lenses of chick embryos are removed and explanted for culturing. After several days of culturing, the epithelial cells differentiate into lens fiber cells. The rate of differentiation is observed by microscope laser light scattering spectroscopy in terms of crystallin production as a function of embryo age. The data are compared with the completed analysis on the accumulation of crystallins in intact lens tissue at different stages of development. (2) Actin is a principal protein within the cytoplasm of all eukaryotic cells and mammalian muscle tissue. Actin along with a myriad of binding and destabilizing proteins contributes to the overall structure and function of the cytoplasmic matrix. The study of the effects of binding and destabilizing proteins on the structure of actin networks elucidates the role of the cytoplasmic matrix in cell regulation. The investigators employ several techniques like microscope laser light scattering spectroscopy, viscometry and electron microscopy to determine the thixotropic sol and gel transitions of actin and actin complexed solutions. (3) The physico-chemical state of bile as secreted within the canalicular space of isolated rat hepatocyte couplets is studied in order to understand gall stone disease. Several physiologic and pathologic agents are used to determine the physico-chemical state of a primary bile under choleric and cholestatic conditions.

Professor David Pritchard's group has obtained the first radio frequency spectra from atoms confined in a magnetic trap. These spectra were diagnostic of the atoms' energy distribution, and showed that the sodium atoms 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 continues his investigations of highly excited atoms in a strong magnetic field using high resolution laser spectroscopy. The most recent efforts were designed to verify the absolute accuracy to which the energy and magnetic field can be determined, to confirm the results of numerical calculations on the diamagnetic structure of lithium Rydberg states, and to illustrate anticrossings among the diamagnetic levels. Now confident in the reliability of the measurement technique and aware of its limitations, Professor Kleppner will enter energy and field regimes where present theoretical analyses are inadequate. The research probes the existence of certain symmetries of the system Hamiltonian, and how these may effect detailed and gross properties of the spectrum.

Professor Alan J. Grodzinsky and his students (Department of Electrical Engineering and Computer Science) along with Dr. Martin Yarmush (Chemical Engineering) have found that electric fields can significantly alter the intermolecular spacing and permeability of polyelectrolyte gel membranes. The field can selectively alter intramembrane pH or ionic strength. A model for the kinetics of this interaction suggest that both mechanical (gel) and electrochemical processes are rate-controlling. The result is a significant alteration in the flux of fluorescently tagged proteins, with application to feedback controlled protein separation and purification, and on demand drug delivery.

Professor Feld and Drs. Dasari, Michael Otteson and J. Timothy Hutton 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 shortlived ($1\mu\text{s}$) ^{85}Rb atoms. Present experiments seek to obtain sub-Doppler resolution anisotropy signals, which should allow 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 $^{85}\text{Kr} - ^{85}\text{Rb}$. 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. Dasari have investigated a variety of quantum transport phenomena in atomic and molecular vapors using laser photon echo techniques. Experiments have studied quantum superposition state scattering, for which there is no-classical analog. Results include direct inversion of two pulse echo data to obtain two-level optical radiator velocity changing collision kernels with a few cm/s resolution, magnetic state scattering kernels for isolated multipole moments, and development of a new tunable energy compensation technique to resolve changes accompanying collision-induced molecular radiator reorientation.

Professor Feld and Drs. Carter Kittrell and Firooz Partovi, both of the Spectroscopy Laboratory, are engaged in biomedical research to understand the mechanisms governing laser ablation of tissue, for laser microsurgery and various percutaneous applications. A theory of thermal laser ablation has been formulated, and the dosimetry and damage predictions have been confirmed in experiments in human cadaver arteries using blue-green light. In addition, laser-induced fluorescence has been used to distinguish plaque, blood, and normal artery wall, and then to construct spectral maps of the interior of the artery. The technique has also been applied to the diagnosis of superficial bladder carcinoma and the results are promising. Part of this work has been conducted jointly with Dr. John Kramer of the Department of Cardiology of the Cleveland Clinic Foundation and Dr. Sipke Strikwerda of the Department of Cardiology of Leiden University Hospital. In parallel with this work, Drs. Feld, Kramer and Kittrell and Dr. Barry Sacks of Leonard Morse Hospital, Natick Ma., along with Drs. Floyd Loop and Bruce Lytle of the Thoracic and Cardiovascular Surgery Department of the Cleveland Clinic Foundation, are developing a clinical system for diagnosing and treating arteriosclerosis using laser light delivered percutaneously through optical fibers.

Professor Feld and his colleagues are continuing experiments to study the interaction of single atoms with an open optical cavity. Results include enhancement and suppression of spontaneous emission as well as radiative level shifts of a visible atomic resonance line. Recent preliminary results of experiments with an optical cavity having higher finesse show larger line width enhancement, suppression and level shifts than previous experiments. Future experiments will include study of atom-cavity coupling states as well as the 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

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. In addition, it provides computing and electronics facilities for its programs. The primary experimental programs are in three areas. The largest local effort is in intermediate energy nuclear physics, centered at the Bates Linear Accelerator Center in Middleton, Massachusetts. 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 Laboratory (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. A third field is relativistic heavy ion physics with activities at Brookhaven National Laboratory (BNL).

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 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 the 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, Robert Lourie, 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. The results should be available in about one year.

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.

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, the momentum transfer dependence of the reaction has been revealed, excluding several proposals involving significant modification of nucleon structure in the medium. 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 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 preliminary results are surprising in showing that the neutron cross section is larger than that from protons.

A unique test of the unified theory of electromagnetic and weak interactions is in progress 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 asymmetry has now been measured to the level of 6×10^{-7} ; the experimenters hope to reduce this by yet another order of magnitude. Upon completion of the parity experiment, 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 will be built for use at the Paul Scherrer Institute (PSI).

The hypernuclei and solar neutrino group has joined the LVD collaboration at the Gran Sasso Laboratory in Italy in order to study cosmic neutrinos. Developments relevant to a future neutral current detector using inelastic neutrino scattering are being pursued.

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). 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.

The studies of these phenomena has 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 preliminary result is the large relative increase in the K^+/p^+ 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.

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. In the coming years we will accelerate heavier nuclei to higher energies so as to reach further into the extremes of mass and density, extremes which will eventually approximate those that are conjectured to have occurred in the early stages of the expanding universe.

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 construction of the L3 detector at the LEP accelerator at CERN, 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 is distinct from the other LEP and SLC detectors and therefore provides the opportunity to explore and understand unique physics phenomena. The purpose of the L3 experiment is to study photons, electrons and muons very precisely. 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), are being followed and design values are being 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 $BL^2 = 160\text{kg}\cdot\text{m}^2$ so that the central part of the detector can be easily modified or removed, making this experiment readily adaptable for future phases of LEP.

In addition to the unprecedented scale and standard of precision of the detector, a strict timetable is being 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.

UA1 Experiment

The UA1 group is studying proton-antiproton collisions at the CERN SppS Collider in Geneva, Switzerland. The physicists in UA1 are investigating many exciting phenomena in particle physics. After its discovery of the W⁺ and Z⁰ 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 B⁰ and B_s⁰ mesons; such a mixing has only been observed so far in the K⁺-K⁻ 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-TMP (tetramethylpentane) calorimeter which is in preparation. In the meantime CERN is constructing a new antiproton accumulator which will allow an increase by a factor of 10 in the size of the data sample.

The Accelerator Physics Collaboration (APC) is conducting experimental research on the nature and interactions of photons, hadrons, and neutrinos. An experiment at FNAL completed three years ago, was designed to study how hadrons made up of one set of quarks generate hadrons with other types of quarks or other combinations of the same type of quarks. For this study, a unique device was developed that identifies each particle produced. The device, called CRISIS, worked well and should give new information. The data from this experiment are currently being analyzed. Several papers have been published and six students have received their Ph.D. from this work. Studies are continuing on the question of hadron-nucleus collisions. This topic is of great interest, not only for high energy physics, but also for heavy ion physics.

The group has taken data at FNAL in the world's highest energy neutrino beam. In this experiment one will be looking at a new domain in neutrino physics where new phenomena might be found. This experiment used a holographic bubble chamber. The holographic bubble chamber is a new technique which takes a holographic picture of the bubble chambers. This technique, developed at MIT, will provide a factor of ten improvement in resolution over conventional bubble chamber pictures. As noted above, the chamber has been built, is currently operating, and meets all specifications. All of these experiments are being done in collaboration with a consortium of universities in Japan, China, Israel, Italy, France, and the United States.

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 (CSC) Group in a collaborative effort has constructed a major new detector for high energy neutrinos at FNAL. The initial experimental program for this apparatus is the detailed study of the weak neutral currents predicted on the basis of the electroweak theory and was discovered experimentally several years ago. An experiment has been performed to study the nucleon structure functions associated with the neutral weak current. This detector, consisting of 350 tons of instrumented target material followed by a muon spectrometer, is now being used for a continuation of these studies with the newly commissioned Tevatron. The group is also collaborating in the construction of a high energy muon scattering facility at Fermilab which will be used with the Tevatron to study nucleon structure as well as the dynamics of quark jets in nuclear matter.

The major long term focus of the group is in the construction and exploitation of a new "state of the art" particle detector for use at the Stanford Linear Collider (SLC). This detector called the Stanford Large Detector (SLD) is now under construction and the CSC Group has a major responsibility for construction of the warm iron hadron calorimeter and muon detector.

The physics that will be proposed with this device is very exciting, and includes studies of the intermediate neutral boson (Z^0), search for the Higgs meson, and search for new leptons and super symmetric particles.

Lepton Quark Studies (LQS)

The LQS group is a collaborator on the SLD experiment, to be performed with the Stanford Linear Collider (SLC) at the Stanford Linear Accelerator Center (SLAC). The group is presently involved in the construction of the Central Drift Chamber, a vital component used in the tracking of charged particles through the detector. Tracking data from this drift chamber is to be used in conjunction with calorimeter and vertex detector information in order to identify various charged particles. This identification is crucial for searching for the fundamental Higgs boson and also in establishing the possible presence of new composite particles such as heavy-quark mesons and new gauge-like bosons. It is also crucial for the studies of the known Z-boson decays in order to test the limits of the present gauge theory. The detector is scheduled for completion about the middle of 1989 and it is hoped that data will be taken toward the end of 1989.

The Center for Theoretical Physics

Particle Theory The "standard theories" of the interaction of quarks and leptons through gauge fields are quantum chromodynamics (QCD) for the strong interactions, the Weinberg-Salam-Glashow Theory for the electromagnetic and weak interactions and general relativity for gravitational interactions. They are powerful and in complete agreement with experiment, but they contain no answers to the fundamental question, why this particular hierarchy of particles and interactions? The theory of super-strings endeavors to unite all physics at the Planck scale, where quantum effects in gravitation start to dominate. Since this scale is totally inaccessible to experiment, this theory makes great use of internal consistency requirements. Though we know a beautiful formulation of the theory as an infinite series of terms corresponding to increasingly topologically complex surfaces, we do not have a field

theory of superstrings on the model of the standard theories. A major continuing effort of members of the Particle Theory Group has been to construct such a theory, using a combination of algebraic and geometrical techniques.

As a test of our understanding of quantum gravity, members of the group have studied whether it is in principle possible to create a whole new inflationary universe "in the laboratory", i.e., out of a concentration of energy in a small region. Applications of ideas from particle physics to cosmology have been an important area of research. The various kinds of topological defects which exist in many fields theories could have an essential part in the development of our universe; in particular cosmic vortex-strings could be associated with galaxy formation. Members of the group have been studying this problem by both analytical and numerical methods. Many of these astrophysics and cosmological studies concern quantum field theory applied to systems not in thermal equilibrium. Members of the group have developed variational techniques for dealing with such situations.

Much of the group's work on the application of the standard theories has been concerned with the question of reconciling with the basic theories useful models that describe the phenomena more or less directly. Members of the group have studied what recent experiments tell us about the strange quark content of the proton and suggest further measurements; they analyze the apparent contradiction between these measurements and the simple quark models that describe the baryons so well. They are investigating whether the model of the baryon as a soliton of an effective meson theory in fact contains more information about the quark degrees of freedom than has been thought. An example of the kind of standard theory analysis that can be done in anticipation of experiments at higher energies is the reexamination of what we know about the possible mass of the Higgs boson. If there are sufficiently massive quarks or leptons, the standard theory Higgs boson could be very light. Analysis of the decays of K and B mesons has placed a lower limit on the Higgs mass.

Nuclear Theory The Nuclear Theory Group addresses a broad range of problems in contemporary nuclear physics. The research program combines new initiatives in emerging fields with active ongoing efforts in areas in which MIT has traditionally played a leading role. Theoretical research continues to benefit from strong interactions with experimentalists in electromagnetic and relativistic heavy ion physics and contributes significantly to these experimental programs.

Hadronic physics and the role of Quantum Chromodynamics (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 confinement are exploring the role of color deformed states, chromomagnetic monopoles, the quantum mechanics of a multiply connected space, the ground state wave functional of pure Yang-Mills theory, and classical Yang-Mills solutions. The general theoretical problem of how to formulate effective operators in hadronic degrees of freedom relevant to conventional low energy

nuclear physics is being studied in the context of a non-relativistic confining quark model. The bag model, which economically enforces the confinement aspects of QCD, is being used to explore the possibility of observing multi-quark resonances in hadron scattering. A complementary description motivated by the large N limit of QCD, in which the only relevant degrees of freedom are meson fields, is being explored by studies of chiral and Skyrme models.

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 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. Hence, particular theoretical effort has been devoted to the quantitative study of charm production and possible compensating processes.

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, and recent efforts have focussed on understanding the nature of periodic solutions to multidimensional classical systems and field theories and calculating periodic solutions for physical processes. Stochastic solution of many-body problems has proven valuable in a variety of applications, in addition to lattice gauge theory, ranging from the exact solution of non-relativistic models with static two-body interactions to calculation of the thermodynamic properties of quantum spin systems. An example of the strong interplay between many-body theory and field theory is the recent exploitation of the analogy between "deformed" gluon states in QCD and deformed nuclei.

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 the South Hall Ring project. Much of the current work addresses coincidence experiments, ranging from fundamental studies of the reaction mechanism in proton knockout experiments, to explanations of how spin observables in coincidence experiments can be exploited to reveal new features of nuclear structure. 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, study of isospin mixing in parity violation experiments, and investigation of a new phase of QED relevant to the anomalous positron peaks in heavy ion collisions. Activities in intermediate energy physics also include the study of the pion optical potential, pion nucleus scattering, and pion production.

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 1988 from the contract with the US Department of Energy (DOE) is expected to total 25,670,000. This sum breaks down as follows: Operations costs (salaries, wages, materials, services, travel and overhead) were \$16,675,000, of this \$5,555,000 was for experimental and theoretical high energy physics, \$9,319,000 was for intermediate nuclear energy physics for the support of the Bates Linac Facility and research program both at Bates and elsewhere, and \$1,781,000 for heavy ion experiments. Equipment costs are expected to total \$7,945,000; of this, \$6,745,000 will be for high energy physics and \$1,200,000 for medium energy and heavy ion physics. A total of \$1,050,000 will be expended for accelerator improvement and general plant and 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 \$160,000.

A. K. KERMAN

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 ~501Amps), 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 nuclear physics during the last several years.

The laboratory 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 will be 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 BU-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.

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. 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 continues to pursue an experiment aimed at providing a unique test of the unified theory of electromagnetic and weak interactions. The experiment will measure the very small asymmetry expected ($\sim 10^{-6}$) in the elastic scattering of electrons with spin aligned parallel or antiparallel to the beam direction. Substantial progress has been made recently. The asymmetry has now been measured down to 6×10^{-7} . The ultimate goal is a result with a factor of ten less uncertainty. Following this experiment, we anticipate in Fiscal Year 1989 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.

The most significant event in the last year was the approval by the Department of Energy of a major facility upgrade. 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 CW beams will allow vigorous coincidence studies. 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.

E. J. MONIZ

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 were carried out by Dr. Edward Dunham, Mark Griffith (grad), and David Osip (Class of 1989). Most of these involved improvements to the cryogenic and vacuum systems associated with the 24-inch telescope. Byron Williams (Class of 1988), supervised by Dr. Dunham, completed the design of a 5:1 optical reduction system for the 24-inch telescope, which will increase the area of sky covered by a CCD frame by a factor of 25.

A new operating mode for SNAPSHOT CCD camera was implemented by Dr. Dunham. This mode works with the telescope fixed, letting the rotation of the Earth trail long strips of sky across the CCD chip. After the new 5:1 optics have been installed, about 4 square degrees of sky per hour can be imaged with the SNAPSHOT.

Last fall 66 students in 12S23 Observing the Stars and Planets and 8.287J-12.117J Observational Techniques of Optical Astronomy, taught by Dr. Linda French and Professor James Elliot, used the observatory for their laboratory work. In the spring, 32 students from 12S23 also used the observatory facilities.

Observing programs included lunar occultation work by Dr. Dunham and Mark Griffith, as well as astrometric research by Amanda Bosh (grad) and Linda Cordella (Class of 1990).

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. Extensive work on the planning and implementation of this system was done this year by Richard Baron (grad), Bill Robert (Class of 1990), and Suzan DeFreitas (Class of 1990). Several alternatives for the high speed link are under consideration. We hope that support for implementing the high speed link will be found soon.

JAMES L. ELLIOT

VICE PRESIDENT, EQUAL OPPORTUNITY OFFICER, AND SECRETARY OF THE CORPORATION

This year was one of the most intensive years at MIT in my memory. It was a year filled with pressure and tension, gains and frustrations, sadness, thrill and joy. An MIT classic.

Following custom, my annual report on the activities of the Corporation is written separately and included with the group of reports in this section.

The departmental reports that follow this introduction chronicle major events, activities, changes and achievements of the academic year in Admissions, Career Services, Athletics, Health Services, Personnel, Public Relations and the MIT Press. As in the past, the achievements in our areas are the direct result of personal effort and of concerted team work.

The Vice President's Staff Group consists of the seven directors of these departments, two of their senior partners -- the Executive Director of the Medical Department and the Director of the News Office -- and nine staff members who work directly with me, responsible for administration of the President's Office, the Corporation Office, for staff support to the Chairman and the Faculty Committees, for the university's equal opportunity program, and for the development of information systems in our areas.

Four of the staff members in our Group deserve special mention here before I comment about the year's work. First, I would like to welcome to our team and to MIT our new Personnel Officer, Maureen C. Wolfe, and our new colleague Lois A. Graham, who joined us from Resource Development last November as Assistant to the Secretary of the Corporation. Second, I want to give special thanks to my two close associates Susan L. Kendall and Kimberly N. Bagni. Prior to Ms. Graham's arrival last fall, these two colleagues shouldered the grueling details of managing three Corporation visiting committee meetings on top of their own demanding responsibilities in the Vice President's Office. My admiration and gratitude could not go far enough to recognize their extraordinary contribution. They are exemplary members of our team.

EQUAL OPPORTUNITY: A MIXED RECORD

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. Total women and minority employment rose by one percent from the previous year.

Last year President Gray asked MIT's senior officers to highlight the year's equal opportunity efforts in our areas and to comment on the insights we gained from these efforts. As Equal Opportunity Officers for the entire university, Dr. Clarence G. Williams and I must pause to say that, overall, the past year carried a very mixed message: On an issue of the highest priority for MIT -- to increase the number of minority faculty -- last year represented a very discouraging picture indeed. Out of a total of 46 new faculty appointments there was only one new underrepresented minority faculty member. And this has been the experience of the past three years! We have been more successful in recruiting women faculty; out of 46 new faculty appointments in twelve months eight or 17 percent were women. But there is a problem here in retention as we have continued to linger at the 9-10 percent total for women faculty, for the past decade.

Much of the reason for the poor record in underrepresented minority faculty hiring lies, to be sure, in the paucity of the candidate pools, particularly in science and engineering fields. But these results are not acceptable MIT performance, whatever the cause.

In sharp contrast to the faculty situation, however, I am proud to note that the past three years' efforts led by our Director of Admissions have met with very satisfactory results. This fall's enrollment of 170 underrepresented minorities in a Freshman class of 1,000, was a significant increase over the previous MIT record of 134, set last year. The number of Freshman women has continued to be just over one-third of the class for the third year in a row.

Michael Behnke would be quick to give credit to all of his staff and to many other MIT colleagues, notably those in Career Services and Financial Aid, as well as the alumni members of our Educational Council. One individual, however, Associate Director of Admissions Eduardo Grado (Class of 1983), stands out in this area for performance that is without equal. Mr. Grado is the only person I know whose working style can be described as both unassuming and flamboyant! His uncommon blend of personal caring, limitless energy, memory for names and faces of students (and of their parents!) and persuasiveness has earned him something of a national reputation. Generations of future alumni will be in his debt.

When it comes to employment of minorities in the professional staff of the offices for which I am responsible, the results can best be described as modest but promising. In the past year we did best in junior positions with two minority hires in Public Relations, and one each in Career Services, in the MIT Press, and in Athletics. What is promising is that each of these areas had had one or no minority staff members until recently. In the departments where we have had more established minority presence -- Personnel, Medical, Admissions, and the President's Office -- the past year was a modest record of maintaining or making marginal increases to our strength. We can and should do better in these departments and there is some reason to believe that our efforts will pay off during the coming year.

The mixed record in our own service areas is mirrored throughout MIT, with some shining exceptions, including a consistently successful record of recruiting several minority staff in the Office of the Dean for Student Affairs which reports to the Provost, and (of special note) two minority appointments made by the Bursar, in the Financial Operations area.

Fortunately the records of both new hires and promotions of women in the administration of our own areas is very encouraging. Of the seven line managers in the departments that report to me, two are women and three other women are associate or executive directors. Of the 152 new appointments in the administrative staff Institute-wide 72 or 47 percent were women, either new to MIT or promoted from the ranks. Throughout MIT each year we see record numbers of MIT women support staff members who are promoted to the administrative staff. We are equally impressed by the large number of women who sign up for educational and training programs offered to MIT employees by the Personnel Department.

Speaking of leadership exercised by women, I wish to acknowledge the contributions of the Working Group on Support Staff Issues. In its twelfth year of existence, this volunteer group of 50 support and administrative staff members, over 90 percent women, was ably led by Donna M. Kendall of the Financial Aid Staff and Angela Katsos of Resource Development. The Group functions in task forces of volunteers, and four of the seven such task groups produced major reports with recommendations on retirement, support staff classification, working parents and performance evaluation. These reports and the ones that preceded them in past years, have been enormously helpful to the MIT Administration in the continuing development and refinement of personnel policy for support staff.

A few other highlights in the equal opportunity front for this year are in order. Our efforts through participation in the Black Achievers Program of the Greater Boston YMCA continues to provide valuable role models for minority youth. Professor Willard Johnson of the Department of Political Science and Yvonne Gittens, Associate Director of Financial Aid, were recognized as MIT's Black Achievers for 1988. The Assistant Equal Opportunity Officer and Special Assistant to the President contributed to the university's commitment to the local community by serving as President of Massachusetts Pre-Engineering Program (MASSPEP), a program designed to assist minority pre-college students academically to enroll and graduate from a four-year undergraduate engineering and science-based programs. Dr. Williams also served as President of the Greater Boston Inter-University Council, a local organization of minority administrators initiated to develop activities that enhance retention of minority students at Boston metropolitan colleges and universities; and he was recognized in the 100 Listing in Boston, 1988, as one of 100 black men and women whose achievements and involvement have provided inspiration and guidance to others and tangible contributions toward the uplift of black people and black awareness in Boston.

As a postscript to my comments on equal opportunity programs and concerns, I would like to note the appointment, this summer, of an ad hoc Committee on Family and Work. Chaired by Professor Peter Elias, this Committee is charged by the President and the Chairman of the Faculty to study and report on the changing demographics of the MIT community and on the emerging needs that our benefit program and our appointment and other personnel policies should address in order to help MIT adjust to the ways that social trends, changing styles, and pressures in our personal lives interact with our responsibilities at work. I hope to be able to report on the results of this Committee's work next year in my report.

BENEFITS PLANNING, HEALTH OUTREACH AND PUBLIC RELATIONS

As the summer comes to a close, I am very happy indeed to report significant progress in the largest task we have undertaken within our two-year strategic review of MIT benefits. In a few words, we hope that by next year this time we will have implemented an ambitious new unified retirement plan, whose design is the product of intensive team work by the Personnel staff, the Treasurer's Office and Financial Operations staff, and our consultants, under the guidance of a steering committee of senior officers, chaired by Senior Vice President, William R. Dickson.

In addition to the comprehensive Benefits Review several other major projects deserve recognition. Notable among them are the programs of the Medical Department to introduce a new product (the Flexible MIT Health Plan), to assign primary care physicians to all entering students, and to mount major educational campaigns on AIDS and other important health issues. Both in the fall and the spring of last year the Medical staff and the staff of the News Office, along with many other MIT services, had the difficult task of responding to an extraordinary incidence of student suicides and to the sense of loss and shock that the news of these tragedies cast on the entire campus community.

Last year in my report I remarked about the feverish preparations for the MIT Campaign for the future. On October 23, 1987, the Campaign was launched very successfully with gala gatherings and celebrations on campus which, incidentally, occurred only three days after the October crash of the stock market.

I close my report with a brief mention of three jubilant highlights of the year. All three represent monumental commitments of talent and effort by MIT people. Moreover, MIT was the beneficiary of millions of dollars of publicity, world-wide, from two of these events. The three events taken together explain why MIT continues to be a unique and vibrant community that occupies a special place in the minds and the hearts of many of us who work here.

The three events are: First, the announcement of two MIT Nobel laureates in one week in October -- Professors Robert Solow and Susumu Tonegawa. Second, the thrilling flight of the MIT Daedalus human-powered airplane from Crete to Santorini on April 23. And, third, on the same April day, the Johnson Games, MIT's own brand of an Olympiad of fellowship and fun. The Games, of course, were part of the dedication of the MIT Athletics Center in honor of Howard W. Johnson, MIT's 12th President. For the 1,500 members of our community, who assembled at the Steinbrenner Stadium for a day's celebration and friendly competition, there was a sharing of spirit and warmth that was unprecedented in this scale in my twenty-eight years on this campus.

Last year was an MIT classic.

CONSTANTINE B. SIMONIDES

Office of Admissions

The highlight of this year was a significant increase in the number of applications and enrolled students from underrepresented minority groups. Students from these groups will account for 17 percent of this year's freshman class, the highest number and percentage in MIT's history and the highest percentage in the Ivy plus Stanford group. This continues the success experienced last year when the percentage of underrepresented minority students in the class increased from 10 to 13. It should be noted that the increase during these two years has been accompanied by an improvement in the academic credentials of incoming minority students.

Some of our competitor colleges and universities also saw increases in minority numbers. This may be due to the national response to a decrease in the enrollment of minority students in higher education. In any case, MIT's level of success is unusual even in the context of the signs of improvement nationally. Several things may account for the success at either the application or yield stages. We developed a new publication addressing concerns of minority students. In that publication and through other avenues, we publicized the existence of MIT's new program of differential self-help for our lowest income students. The promotion of Eduardo Grado to Associate Director, the addition of Clinton Elliott as Assistant Director, and more funds for travel allowed for more personal contact and visibility. National coverage of the Racial Climate Report may have alerted some people to MIT's concern for minority issues.

We enjoyed a slight increase in total applications. This countered a trend nationally which saw most schools identified with engineering experiencing declines in applications. We did, in fact, receive fewer applications from students expressing an interest in engineering. We hope the increase in over-all applications reflects some continued success in our efforts to attract students with broader interests.

The percentage of women in the entering class fell from 36 percent last year to 33 percent. This is the second year of decline from a high of 38 percent in 1986. This decline mirrors a decline nationally in the number of women considering careers in science and technology. We must try to counter this by working even harder to alert high school students to the breadth of offerings at MIT.

The initiatives we have taken to develop a new marketing strategy received some national recognition. The Council for the Advancement and Support of Education (CASE) awarded us their "Grand Gold" medal for the best college admissions recruitment program. Several components of the program also received gold medals including one for the greatest improvement in marketing.

We completed a much needed renovation of the room housing the graduate, special student and transfer admissions operations. We also made great progress in our use of computers and data processing. Most staff members now have personal computers with easy access to the applicant data base. An inquiry system allows us to eliminate costly duplication of mailings. These improvements, along with continued development of better ways to record and present data, should enable us to operate more efficiently and serve the community more effectively.

MICHAEL C. BEHNKE

ADMISSIONS TRENDS 1979 - 88

	<u>1979</u>	<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>Entrants from Secondary Schools</u>										
Preliminary applications	10,274	11,223	12,526	12,525	12,653	12,465	14,698	14,349	16,237	17,408
Final applications	5,368	5,677	5,922	5,921	5,959	6,055	5,747	6,213	7,372	7,437
Admissions offered	1,813	1,809	1,909	1,911	1,818	1,854	1,885	1,752	1,826	1,833
Actual registration to date	1,057	1,081	1,030	1,109	1,082	1,059	1,061	1,001	1,012	1,003
Registrations as percent of admissions	58.4%	59.7%	54.0%	57.5%	61.1%	57.1%	56.2%	57.0%	55.4%	54.7%
Number of secondary schools represented	893	894	835	842	891	722	860	830	848	844
Percent of students from 9 northeastern states	49.0%	47.8%	51.9%	51.0%	50.5%	50.5%	44.7%	43.5%	39.8%	36.4%
<u>College Transfers</u>										
Total applications	1,143	1,131	818	1,378	1,024	1,048	909	890	870	905
Applications completed	486	471	399	425	400	304	295	317	304	349
Admissions offered	152	167	93	118	128	124	131	137	106	141
Actual registrations	124	119	76	82	91	91	101	97	80	94
Registrations as percent of admissions	82%	71%	82%	69%	71%	73%	77%	71%	69%	69%
<u>Graduate Students</u>										
Total applications	7,849	7,832	9,075	9,342	8,836	7,922	8,032	8,564	8,443	8,863
Admissions offered	2,636	2,380	2,926	2,920	3,007	2,223	2,467	2,457	2,243	2,101
Actual registrations	1,362	1,212	1,465	1,476	1,542	1,290	1,338	1,105	1,019	1,104
Registrations as percent of admissions	52%	51%	50%	51%	51%	58%	54%	49%	45%	53%

Educational Council

Over 1600 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 258 women and 63 minorities (45 Blacks, 7 Puerto Ricans, and 11 Mexican-Americans). The Educational Counselors represented MIT at 260 local College Fair programs; they conducted over 7,400 admissions interviews, and held countless conversations with prospective MIT students and with local school personnel. Of all MIT applicants, 94.3 percent (95.5 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 325 students, representing 150 different geographic areas (including 20 foreign countries), participated in this program run by the Educational Council Office.

Meetings for newly admitted students were held in 36 cities throughout the United States by Educational Council groups. Twenty-five 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 106 Central Meetings in 93 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 85 volunteers, all women professionals (from AMITA, SWE, AWIS, AWM, or other women's professional organizations) to visit 40 high schools throughout the Greater Boston Metropolitan Area. They spread the word to young women (and in some cases young men) about the importance of continuing to study math and science in order to keep career options open. A High School Visiting Program was run in Los Angeles as a joint effort with Cal Tech.

BONNY S. KELLERMANN

Department of Athletics

I. Overview

The 1987-88 academic year has been one of consolidation including a close examination of what we are currently doing and how we might function more efficiently and effectively. In this regard I have been particularly gratified by the commitment and accomplishments of full-time and part-time Athletic Department administrative staff, coaches, instructors and support groups.

We have integrated successfully: (1) the series of senior management organizational shifts (2) the addition of Women's Soccer, Women's Skiing and Men's Volleyball into the intercollegiate program (3) the new leadership and reorganization of Men's and Women's Crew - our largest intercollegiate program. The structural modifications of Alumni Pool to redress the long standing women's space imbalance should be completed by the fall of 1988. We have in place a policy of aggressive cost containment with particular emphasis on intercollegiate scheduling. We have agreed with Physical Plant and the Planning Office on an all-inclusive roster of necessary facility improvements. Efforts have continued and are closer to resolution in developing an appropriate "non-tenure system" to replace our current tenure policy.

With consolidation the year has also proven busier than many with a spring that included the Corporation Visiting Committee for Athletics, the dedication of the Howard W. Johnson Athletics Center and the planning/implementation of the Johnson Games. As Director, my own activities have been unusually stretched with my recent election as president of the Eastern College Athletic Conference and Chair of the 1988 50th Anniversary of the ECAC in addition to on-going responsibilities with the NCAA Executive Committee.

II. Highlights of the 1987-88 Academic Year

With Exhibits I-V attached for comparisons of program, participation and competitive results we are pleased to note record high levels for the period of the last several years in Physical Education undergraduate and total registration and in both male and female intercollegiate competition. Intramurals reflect a higher level than last year and our club programs continue at a high level despite our decision to drop from our roster two dance programs (175+ students) that regretfully should be included with Student Association activities.

Highlights include:

Intercollegiates:

- Men's Gymnastics qualified for the first time ever for the United States Gymnastics Federation Division II-III National Collegiate Championships.
- Women's Volleyball won the New England Women's Eight Tournament.
- Pistol won the Free Pistol Competition at the National Rifle Association National Championships.
- Men's Track and Field won their 4th consecutive New England Division III Indoor Championship and outdoors won the New England Division III title with a record number of points. The Outdoor team finished 9th Nationally.
- A women swimmer, Yvonne Grierson '90 set a national record in winning the 100 yard fly NCAA Division III National Championship - a first for an MIT student.
- Men's basketball, squash, lacrosse and heavyweight crew had the most victories in several years.
- The newly formed Division III Northeast Football Conference of New England private school institutions (Bentley, Merrimack, Assumption, Stonehill, MIT) is poised for a transition year in the fall season of 1988 with full Division III status and round-robin competition planned for the fall season of 1989. Western New England and Nichols will make a decision about joining the new league sometime in 1989.

Club Programs:

- The Student Club concept is being more clearly defined (now three levels: Activity Clubs, Competitive Clubs, and Club Varsity) with formal policies and operating procedures. The objective is to provide a more satisfying experience for our students as well as greater student access and more efficient administrative support for this growing program component.

Intramurals:

- Improved accountability and performance by Student Sport Managers and officials has been achieved through revised hiring and training procedures also leading to improved scheduling and communications.
- Future plans include the creation of a referees club and a much needed updating of the Intramural Constitution.

Physical Education:

- Consistent with a record number of registrations and course offerings we have completed a first-time student evaluation process that covered all four quarters.
- During IAP Physical Education offered 27 courses (24 for credit) involving sixteen of our nineteen full-time instructors. There were 877 registrations of which 495 were for credit.

Facilities:

- Completed the conversion of six outdoor Har-Tru Tennis courts to synthetic all weather. Future plans include the installation of bleachers and the resurfacing of the five already synthetic courts contiguous to those six recently converted.
- Reseeded and generally upgraded Field Area "B" and replaced the Rifle-Pistol Range backstop.
- Future priorities include completion of the Alumni Pool renovation, the conversion to wood flooring for Rockwell Cage, the upgrading of squash court floors, walls and lighting for the Dupont and Alumni Pool courts, the restructuring of the three internal athletic/exercise rooms on the second floor of Dupont Athletic Center, and the improved audio system for the indoor track level of the Johnson Athletic Center.

III. Future Plans

Looking ahead with our own planning and with appropriate responses to the Visiting Committee Report of Spring 1988 I would emphasize we are alert to the concerns of the Visiting Committee with regard to safety. We have already taken several immediate steps of importance at Pierce Boathouse with similar plans for the Health Fitness Center. In addition we have revised our Current Program Priorities (see Exhibit VI and VII) to include a thorough review of our safety concerns and procedures by program and facility. The review will be conducted by Assistant Director for Operations, Rod Arthur, with a committee to include the on-site Directors of the Class of 1974 Health Fitness Center, Alumni Pool, Wood Sailing Pavilion and Pierce Boathouse. With regard to the acceleration and possible expansion of the Phase III Rockwell Cage/Briggs Field House area and consideration for partial funding from the MIT Capital Campaign for the Future we will complete by the Fall of 1988 a comprehensive statement of the Case for Phase III. This will be developed in Cooperation with the Planning Office, Physical Plant and the Development Office. Finally, Physical Education has formed a committee to maintain the initiative of their Visiting Committee presentation on future program relevance and quality through a curriculum balance of "wellness"/health fitness and life-time carry over sport education.

In closing, the year 1987-88 has been an outstanding one for our Department in many regards. We have exhibited greater initiative, team building and leadership at all levels. Instruction and coaching effectiveness have improved even over last years fine performance. Under Assistant Director Francis O'Brien new energy has been given to the organization and enthusiasm of intercollegiate and club sport programs. Paul Grace, Coordinator of Sports Medicine and Equipment has been vigorous and effective in assuming the additional responsibility for equipment purchases and distribution. Morale in the Department has never been higher, in my judgement, with particular credit for that going appropriately to our competent and dedicated clerical support staff who function so cheerfully and as a team of mutually supportive office managers.

Finally, I want to make mention of valued colleagues who will be leaving our Department for career advancement opportunities. My own clerical support colleague, Renee Smith, left in midyear for an office manager position with the Dana Farber Institute. Ms. Shawn Ladda, Head Coach of Women's Soccer and Club Lacrosse is leaving to become Women's Head Coach of Soccer at Columbia University. Michael Kennedy, Part-time Head Coach of Men's and Women's Diving is leaving for a full-time comparable position at Harvard University. They will be missed and leave with our best wishes for success and fulfillment with their new opportunities.

ROYCE N. FLIPPIN, JR.

EXHIBIT I
MIT ATHLETIC PROGRAM PARTICIPATION

	<u>Report Year</u> <u>1987-88</u>	<u>1986-87</u>	<u>1985-86</u>
STUDENT ENROLLMENT (October Figures - Includes Specials)			
Undergrad Women	1,384	1,295	1,165
Undergrad Men	<u>2,993</u>	<u>3,148</u>	<u>3,376</u>
TOTAL	4,377	4,443	4,541
Graduate Women	1,005	1,045	1,042
Graduate Men	<u>4,183</u>	<u>4,268</u>	<u>4,204</u>
TOTAL	<u>5,188</u>	<u>5,313</u>	<u>5,246</u>
GRAND TOTAL STUDENTS	<u>9,565</u>	<u>9,756</u>	<u>9,787</u>

STUDENT PARTICIPATIONS
(Includes Multiple
Activity Duplication)

1. PHYSICAL EDUCATION

Total Registrations	7,482	7,004	6,512
(Undergrad)	(5,918)	(5,672)	(5,324)
(Grad)	(1,098)	(940)	(957)
(Staff)	(466)	(392)	(231)

2. INTRAMURALS (M/W & COED)

Programs	21	22	21
Teams	1,030	1,015	1,077
Students	10,581	10,129	10,555

3. CLUBS

Programs	34	34	35
Students	831	1,076	1,052

4. INTERCOLLEGIATES

<u>Women's Programs</u>	<u>13</u>	<u>12</u>	<u>12</u>
- Student Participants	277	251	211
- Varsity Letter Awards	134	135	142
<u>Men's Programs</u>			
- Student Participants	628	617	582
- Varsity Letter Awards	340	317	330

EXHIBIT II

Physical Education Activities 1987-88
(In Order of Registrations)

<u>Activity</u>	<u>Register & Passed</u>	<u>Activity</u>	<u>Register & Passed</u>
<u>Skating</u>		<u>Squash</u>	
Beginning	490-277	Beginning	244-122
Hockey	158-57	Intermediate	32-16
Figure	74-36		276-138
	<u>722-370</u>		
<u>Tennis</u>		<u>Fencing</u>	218-141
Beginning	410-204	<u>Archery</u>	181-125
Intermediate	218-117	<u>Sculling</u>	148-66
Advanced	30-20	<u>Skiing</u>	143-94
	<u>658-341</u>	<u>Table Tennis</u>	139-83
<u>Wt. Training</u>	647-321	<u>Basketball</u>	128-81
		<u>Badminton</u>	123-75
<u>Aerobics</u>		<u>Golf</u>	116-67
Low Impact	246-121	<u>Frisbee</u>	80-42
Aerobic Dance	383-130	<u>T'ai Chi</u>	71-29
	<u>629-251</u>	<u>Lacrosse</u>	
<u>Dance</u>		Outdoor	49-24
Partner Dance	225-129	Indoor	9-3
Folk Dance	33-15		<u>58-27</u>
Square Dance	11-7	<u>Diving</u>	51-36
Jazz I	96-38	<u>Judo</u>	49-26
Jazz II	47-27	<u>Rugby</u>	44-32
Ballet I	39-17	<u>Tae Kwon Do</u>	41-21
Ballet II	52-29	<u>Softball</u>	33-24
Jazz/Ballet	24-7	<u>Officiating</u>	
	<u>527-269</u>	First Qtr.	14-7
<u>Exercise Fitness</u>	437-192	Second Qtr.	17-11
			<u>31-18</u>
<u>Swimming</u>		<u>Rowing (Ex.)</u>	24-10
Beginning	185-119	<u>Bicycling</u>	19-0
Adv. Beginning	144-62	<u>Wrestling</u>	17-5
Intermediate	44-15	<u>Indoor Soccer</u>	16-11
Adv. Techniques	12-7	<u>Touch Football</u>	15-13
Scuba	31-29	<u>Rifle</u>	11-11
Adv. Lifesaving I	26-21		
Adv. Lifesaving II	22-17		
	<u>464-270</u>		
<u>Sailing</u>	350-187		
<u>Pistol</u>	341-286		
<u>Yoga</u>	333-158		
<u>Volleyball</u>			
Beginning	261-150		
Intermediate	45-27		
	<u>306-177</u>		
		TOTAL	7482-3997
			Register-Pass

EXHIBIT III

CLUB PROGRAMS PARTICIPATION 1987-88

	Report Year <u>1987-88</u>	<u>1986-87</u>	<u>1985-86</u>
Aikido	15	20	18
Archery	12	12	16
Badminton	30	33	30
Ballroom Dance	Removed	150	147
Bowling	30	16	17
Cheerleading (Football)	14	12	10
Cheerleading (Basketball)	Not Active	14	14
Crew (Grad Women)	16	24	25
Cricket	20	28	26
Dance Club	25	27	20
Fencing	33	35	30
Figure Skating Clubs	65	85	88
Folk Dance	30	42	40
Frisbee	25	66	66
Ice Hockey (Women)	30	32	30
Judo	10	Not Active	12
Karatedo Doshinkan	14	12	10
Korean Karate	25	31	30
Lacrosse (Women)	23	25	31
Outing (White Water)	20	21	20
Rifle/Pistol	45	53	51
Rugby (Men)	40	50	45
Rugby (Women)	20	14	16
Scuba	25	24	24
Shorinji Kempo	10		
Shotokan Karate	25	30	26
SKA Karate	25	30	26
Soccer (Grad Men)	35	28	27
Square Dance	Removed	25	23
Swimming (Masters)	35	32	30
Table Tennis	15	30	24
Tae Kwon Do	30	26	27
Water Polo (Women)	22	20	17
Water Polo (Men)	25		
Wonhwa-Do	15	22	20
Wu-Tang (Boston)	15	14	17
Wu-Tang (MIT)	12	18	17
<hr/>			
TOTAL PARTICIPANTS	831	1,076	1,052
TOTAL PROGRAMS	34(1)	34	35

(1) Note: Ballroom and Square Dance are transferred from the Athletic Roster effective 1987-88.

EXHIBIT IV

INTRAMURAL PARTICIPATION

Sport	1987-88		1986-87	
	# Teams	Participation	#Teams	Participation
Badminton	40	200	41	205
Basketball	141	1128	110	880
Cross Country	6	88	5	59
Cycling	6	34	11	108
Fencing	4	19	5	28
Football	77	1155	80	1200
Frisbee	52	520	45	450
Hockey	92	1104	86	1032
Octathon	16	240		INACTIVE
Rugby 7's	12	84	12	84
Rugby 10's	12	120	12	120
Soccer	80	1360	70	1190
Indoor Soccer		INACTIVE	12	120
Softball	134	1876	130	1820
Squash	25	125	46	230
Swimming		INACTIVE	5	62
Table Tennis	49	343	43	301
Team Tennis	31	124	48	192
Indoor Track	8	87	4	39
Triathlon	19	101	20	110
Volleyball	181	1448	196	1568
Water Polo	39	390	29	290
Wrestling	6	35	5	41
	21 Programs		22 Programs	
	1,030 Teams		1,015 Teams	
	10,581 Cumulative		10,129 Cumulative	
	Participants		Participants	

87-88 Deleted: Indoor Soccer & Swimming
 Added : Octathon

EXHIBIT V

MIT VARSITY RECORDS IN INTERCOLLEGIATE COMPETITION

1987-88

MEN'S SPORTS (24) (A)

FALL (MEN)	Won	Loss	Tie
Cross Country	4	2	0
Football	4	5	0
Golf (B)	4	4	0
Soccer	5	7	3
Water Polo	8	11	0

WINTER (MEN)

Basketball	11	15	0
Fencing	7	12	0
Gymnastics	4	4	0
Ice Hockey	8	10	0
Pistol	11	6	0
Squash	13	11	0
Swimming	4	4	0
Track, Indoor	9	0	0
Wrestling	11	6	0

SPRING (MEN)

Baseball	11	16	0
Crew, Heavy	3	6	0
Crew, Light	1	4	0
Golf	9	3	0
Lacrosse	9	5	0
Tennis (B)	10	16	0
Track, Outdoor	5	0	0
Volleyball	17	13	0

1987-88 Totals 168-160-3 (.512)
vs. Previous Year 203-144-4 (.584)

WOMEN'S SPORTS (13) (C)

FALL (WOMEN)	Won	Loss	Tie
Cross Country	4	1	0
Field Hockey	6	9	0
Soccer	3	15	0
Volleyball	23	11	0

WINTER (WOMEN)

Basketball	2	24	0
Fencing	11	8	0
Gymnastics	3	6	0
Swimming	7	3	0

SPRING (WOMEN)

Crew	5	4	0
Softball	10	7	0
Tennis (B)	11	6	0

1987-88 Totals 85-94-0 (.475)
vs. Previous Year 92-74-1 (.554)

(A) No won-loss record for rifle, sailing and skiing.

(B) Golf and Tennis play a combined Fall/Spring Schedule.

(C) No Won-Loss record for sailing and Skiing.

EXHIBIT VI

June, 1988

MIT DEPARTMENT OF ATHLETICS
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) OBJECTIVES

- Recruit and hire quality people, review and evaluate on a regular basis in on-going development 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 undergraduate profile (more women; less men; more graduate students - both in total and housed on campus).
- Stress the relevance and quality of physical education programs in the MIT educational context and the student community.
- Support and develop modern health fitness programs; gradually expand 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.
- Gradually consolidate Athletic Department responsibility for all inside and outside maintenance and building services associated with athletic programs.
- Develop and integrate an aggressive, on-going policy of cost containment in all budgetary and operating procedures. Assume future budget squeezes.
- Sustain a close relationship with Admissions in the on-going quest for highest quality students.

EXHIBIT VII

June, 1988

MIT DEPARTMENT OF ATHLETICS

Current Program Priorities

(Through FY 1989)

1. Review and upgrade all matters of safety condition, supervision and procedures for all appropriate programs and facilities.
2. Introduce new financial systems to improve operating efficiencies; reduce operating expenses; consolidate 37 intercollegiate sports program.
3. Recruit and hire minority faculty/staff.
4. Complete review of Athletic Department tenure system and determine future structure.
5. Complete Alumni Pool renovation to redress space inequities for women; improve opportunities for Intercollegiate weight training; initiate building plans and funding for Phase III, 50 meter swimming pool.
6. Improve quality and relevance of Physical Education course offerings; support the P/E leadership in professional staff training and evaluation; re-examine philosophy and practice of non-course credit. Visiting Committee April 13-14, 1988 will focus on Physical Education.
7. Transfer Physical Plant Field maintenance work force to Athletics Department.

Career Services and Preprofessional Advising

The October slide in the stock market which dampened the mood on Wall Street for the rest of the year did little to discourage the economy. Rising production translated itself into a healthy demand for MIT graduates. Even Wall Street came recruiting.

A total of 423 employers came through the office, exactly the same number as the year before. They included 19 government agencies, 14 architectural firms, 3 educational organizations seeking teachers, 15 management consulting firms (loosely defined), and 28 banks and investment houses. In addition, 11 professional schools came to talk with students about their graduate programs.

Interviewing by students was light in the fall term, perhaps because they thought employers would be retrenching, but by year end over 1,600 students had had some 9,600 interviews. The student count was the highest ever. The interview count was a noticeable drop from last year's figure of 10,500 but above the level of 1984-85 or 1985-86.

Salary offers presented a mixed picture. Bachelors in aeronautics and astronautics and in mechanical engineering saw little or no increase over 1986-87. Bachelors in electrical engineering received offers which were 3.1 percent higher (less than the inflation rate). Bachelors in chemical engineering, who have been in short supply since the collapse in oil prices in 1982 scared students away from the field, received offers that were 4.3 percent higher (slightly more than the inflation rate). Bachelor's graduates seeing the highest increase in salaries were bachelors in computer science - up 5.4 percent - and bachelors in management science - up 6.6 percent. Median annual salaries were \$30,000 in aeronautics and astronautics, \$31,000 in mechanical engineering and management science, \$31,800 in chemical engineering, \$32,000 in electrical engineering, and \$33,000 in computer science.

Offers to master's graduates were similarly mixed - up over five percent in aeronautics and astronautics and in electrical engineering, up less than three percent in chemical engineering and mechanical engineering. Doctoral candidates in aeronautics and astronautics and in electrical engineering enjoyed the same rising market as master's candidates in those fields. The median offer to PhDs in electrical engineering - \$54,700 - was up 6.8 percent over 1986-87. The premium paid for a PhD in electrical engineering over an SB, which was as low as 1.4 in the late 'seventies, is now back up to 1.7, where it was in the late 'sixties. The premium in aeronautics and astronautics and in mechanical engineering is about 1.65. The rising relative value of a PhD in engineering may lead more US students to think the degree is worth getting.

At all degree levels the market for technically trained students has been broadening. It used to be that the roster of recruiting organizations consisted of government laboratories, manufacturing companies, design and construction firms, and public utilities. Today it also includes software firms and firms engaged in the planning and implementation of management information systems, consulting firms giving advice on all kinds of other topics (environmental hazards, employee compensation management strategy, etc.), and banks, brokerage houses, and investment companies.

The employer hiring the most MIT graduates in 1986-87 and probably again this year was an eleven year old West Coast software company, Oracle Corporation. It made ten separate recruiting visits and conducted over 170 interviews. Not more than half a dozen employers - major manufacturing companies and laboratories - saw more students. Two Wall Street firms which had up to one hundred interviews each were Merrill Lynch and Goldman Sachs. A characteristic feature of these companies, and of other companies in their industries, is their willingness to meet students in a variety of disciplines. Oracle, for example, was interested in seeing students at any degree level in any field who had a computer science background. Merrill Lynch and Goldman Sachs stated their requirements even more generally.

Manufacturing firms find themselves in competition with firms offering different job descriptions, a different work setting, different career paths, and a different culture. The contrasts are most obvious in the market for students with computer skills. The same student may be wooed by a computer manufacturer with thousands of employees in plants scattered across the country and by a software consulting firm employing a hundred people in midtown Manhattan. Or the pull is between an aerospace company in Los Angeles and an options and futures trading firm in Chicago.

It is a development which is likely to become more pronounced as the service sector continues to grow and its appetite increases for technically-trained individuals. Many manufacturing firms have not taken note of this new competition. They throw their net out as they have always done or, because of tight budgets, they have even reduced their recruiting efforts. Nevertheless, they are distressed when good fish swim away. To help companies improve their catch at MIT the office joined forces at year end with the Industrial Liaison Program and the Development Office to study how students choose the companies they apply to, and the offer they take, and to review how those companies which recruit most effectively set about it. A special questionnaire was sent to every student graduating in June and visits were planned to a number of companies.

The market is also getting broader in terms of national boundaries. Two Japanese companies recruited American students to work for them in Japan and another recruited for its facility in California. Two American subsidiaries of European firms interviewed students for training programs which would take the recruits to Europe. Many other subsidiaries of European companies recruited for their operations here. Other companies, American and foreign, recruited international students for positions in their home countries. Employers and educational institutions in many countries have taken a new look at the movement of students from the classroom to the work force. In August the director attended an international seminar at Oxford on career counselling and placement which drew participants from 14 countries. During the academic year we had visitors from Britain, Sweden, Germany, and Portugal asking about the career paths of PhD engineers, the means by which American students find summer jobs, and the provision of career services. In June we hosted 45 French personnel directors who came to hear about campus recruiting.

Medical School

There were 111 MIT applicants to medical school, down from 113 in 1986-87. They included 86 undergraduates, 9 graduate students, and 16 alumni. The number of undergraduates was 22 higher than last year, one less than the number in 1985-86. The number of undergraduate candidates has gone down and up again before, so it is too early to say whether this year's count represents a trend. The number of women candidates, however - 50 in all - was the highest ever. It has risen in each of the last three years. To date, 80 percent of the undergraduate applicants have been accepted, close to the same percentage as at this time last year. By the start of the academic year in September 91 percent of last year's undergraduates had been accepted, all the graduate students (there were two of them), and 87 percent of the alumni. The only undergraduates not accepted had C plus averages. We look forward to similar acceptance rates this year.

ROBERT K. WEATHERALL

Medical Department

In presenting the 1987-1988 annual report of the Medical Department, a fair statement would be that the Department has consolidated leadership, has identified new strengths in administration, has achieved or is in the process of achieving many of its goals and has in active planning a variety of exciting new initiatives.

Perhaps best symbolizing the corporate hard work of the Medical Department was the site visit of the Joint Commission on Accreditation of Healthcare Organizations in November 1987, which resulted in a full three-year accreditation. There were laudatory comments about the organization and practice within our healthcare facility. A great deal of credit goes to Dr. Bruce Biller and to Rochelle Alexander for their leadership role in this major departmental effort.

Chapter 351 of the Commonwealth of Massachusetts established a patient care assessment program that has been in operation for a year. Our original program, approved by the Board of Registration in Medicine, required revision of our Bylaws and credentialing process. Dr. Stephen Healey serves as Coordinator for this activity that insures quality of care through able providers.

Planning within the Medical Department has centered around the development of a new product. At a number of meetings during the Spring of 1988, presentations were made to the Medical Management Board of the Department. The new product will be attractive to both MIT Health Plan subscribers as well as those in competing indemnity plans. Much credit goes to Dr. J. Christian Kryder, Assistant Medical Director for Operations and Systems, the major planner in the development of the new product.

The clinical laboratory service has been brought in-house under the able leadership of Daniel Manning, and currently many tests previously done elsewhere are now on line at MIT. Oversight of the laboratory is under the direction of the Pathology Department of The Cambridge Hospital, a branch of the department at Massachusetts General Hospital, and directed by Dr. Katharine Kosinski.

Primary care providers of the Department continued to meet during this past year to discuss care of patients, at MIT and also when patients are hospitalized at other institutions. As a result of these meetings there is a better understanding of physician practices. We developed a report form for consultations, established the principle of primary physician visits to patients in outlying hospitals and reviewed the most widely used subspecialties.

The student health initiative, launched with the entering class in 1987, met with considerable success. The personal physician program involved approximately half of the Freshman class and one third of the graduate students. The remainder in each group served as controls. The program is being evaluated now as part of a survey designed to investigate three major areas: 1) the perceptions of students regarding ease of establishing physician-patient contacts; 2) assessment of the level of AIDS knowledge and attitudes towards AIDS-related issues; 3) develop a sense of what are other areas for activity, as for example nutrition and stress reduction for healthier living. Preliminary results of the survey suggest that a significant portion of the students that were assigned physicians appreciated the program. Just to have a name of someone to call was most reassuring. It is planned to expand the program for the academic year 1988-89, to include the entire Freshman class and the first year graduate students. Dr. Mark Goldstein, Chief of the Student Health Services, and Janet Van Ness, Head of the Health Education Service, have been major participants in this initiative. The Medical Department has also been energetically involved in a variety of other educational activities. Members of the Department participated in the Independent Activities Period in January, contributed in a number of orientation exercises, and in ongoing courses at MIT. Meetings around topics like AIDS in minorities, cancer, stress at MIT and staying healthy at MIT were held in living areas. Members of the Department continue to teach in Introduction to Clinical Medicine courses for biotechnology students in the Health, Science and Technology (HST) program and plans are underway for the initiation of a new course introducing first year HST students to the care of the patient. The improvements in the Department's medical and administrative services appeared in a number of other areas. After almost a year of planning we now have 24-hour a day, seven days a week physician coverage for the various patient care areas of the Department. This effort, organized in large part by Dr. Kryder, involves the input of clinical fellows and senior residents from Massachusetts General, Brigham & Women's and Mount Auburn Hospitals. Administrative support for medical operations has been greatly improved with the hiring of Anthony W. Rogers as Senior Manager for Operations. Under Mr. Rogers' innovative leadership mechanisms for problem solving, training and development among support staff, and upgrading of medical records has provided an enormous improvement in efficiency of our operation. In the pharmacy an evening shift to handle refills has been successfully implemented as a 24-hour telephone call-in service, greatly reducing the stress on the daytime staff and allowing that staff to serve the MIT community more effectively during the daytime hours. Much credit for the

concept and innovation of this services goes to David Bailey, Chief Pharmacist. The passing of another year means a number of changes, appointments and resignations, in personnel that affect our overall involvement with the MIT community. These staff changes include the following:

APPOINTMENTS:

Charles Billings	June 8, 1987	Industrial Hygiene Engineer, EMS
Patti Augeri	June 29, 1987	Optometrist
Trude Kleinschmidt	July 1, 1987	Post Doctoral Fellow, Psychiatry
Jane Lubin	July 1, 1987	Ophthalmologist
Heather Ryan	July 20, 1987	Manager for Finance and Analysis, MIT Health Plans
Khadjik Niukian	July 24, 1987	Dentist
Anthony Rogers	July 27, 1987	Senior Manager for Operations
Nancy Barbour	August 1, 1987	Industrial Hygiene Technologist, EMS
Carol Tereszkievicz	August 17, 1987	Physician
Nancy Weiland	November 1, 1987	Marketing and Enrollment Administrator
Daniel Manning	November 23, 1987	Chief Medical Technologist
Pamela Ruprecht	December 1, 1987	Inpatient Nurse
Anne Gilligan	January 11, 1988	Student Health Educator
Laura Willett	February 1, 1988	Physician
David Smith	February 16, 1988	Physician
Anthony Cannata	March 21, 1988	Industrial Hygiene Technologist, EMS
Dawn Metcalf	April 11, 1988	Social Worker/Discharge Planner
Dolores Vidal	April 11, 1988	Nurse Coordinator, Ob/Gyn Service
Mary Hertema	May 1, 1988	Marketing and Enrollment Administrator
Marsha Mealey	May 23, 1988	Industrial Hygiene Technologist, EMS

RESIGNATIONS/RETIREMENTS:

Judy Melagrano	June 30, 1987	Manager, Dietary Service
Jeffrey Rimpas	August 14, 1987	Marketing Coordinator
Sharon Haggerty	October 1, 1987	Nurse Practitioner
Sharon Manus	October 4, 1987	Nurse Coordinator, Ob/Gyn Service
Julia Waldron	November 30, 1987	Nurse Practitioner
George Boylen	December 1, 1987	Industrial Hygiene Chemist, EMS (Retirement)
Ev a Lyons	December 31, 1987	Coordinator of Enrollment Services
Anita Bailey	January 3, 1988	Inpatient Nurse
Nancy Weiland	March 9, 1988	Marketing and Enrollment Administrator

The following sections present information on a number of specific areas of activity:

Nursing Service

In addition to dedicated work in all areas of patient care, ambulatory, Off-hours, and Inpatient Services, the Nursing Service also dedicated an enormous amount of effort to quality assurance monitoring activities and to nursing education, with the development of eight programs during the past year. Janet Beyer temporarily accepted an assignment to work with the medical service at Wellesley College from January through May of 1988, participating in patient care and demonstrating the important role of the nurse practitioner on the healthcare provider team. Nursing personnel also participated in a variety of Department infection control activities including screening of over 150 employees for hepatitis B susceptibility and the provision of vaccine to appropriate individuals. In a period in time when nursing shortages are rampant in many areas, including the greater Boston area, we have been blessed with a stable and outstandingly qualified group of nurses and nurse practitioners.

Social Work Service

An additional experienced medical and clinical social worker, Dawn Metcalf, provided an enormous boost and allowed expansion of the role of the Service especially in planning for after hospital care. The current regulatory environment and the increased utilization of the Inpatient Unit, including plans to begin to care for Medicare individuals in the near future, makes Ms. Metcalf's presence especially important. New treatment groups were added for adult children of alcoholic parents and the Institute Personal Assistance Program continued to be an important function. In addition, a treatment protocol for acutely intoxicated individuals was developed jointly with other members of the Department, Campus Police and the staff of The Cambridge Hospital. This protocol is now in place and being used successfully. There were approximately 300 client contacts per month during the year and over 700 individual requests for services.

Health Education Service

This Service has high visibility and innovative programs in a variety of health areas. More than 5500 members of the MIT community used the resources and expertise of the Service, a growth of 64% over last year and 179% over 1986. In 1987-88 the hiring of a half-time health educator, Anne Gilligan, immediately led to a variety of outreach programs focused predominately on student health education issues. The Service initiated an "AIDS Aware at MIT" activity which was multi-media, multidisciplinary and aimed at all members of the MIT community. Expanding on life stage orientation, a program "Successful Aging Seminars" was debuted, co-sponsored by the MIT Honorary Matrons. The variety of issues for the elderly attracted an average of 58 participants per each of four sessions. Health promotion presence at Lincoln and Draper Laboratories was expanded and issues relating to eating concerns in the college community received great attention jointly with the Dean's Office network program. Topics such as AIDS, Stress Management, Nutrition, Healthy Life Styles, Contraception, Eating Disorders, Human Sexuality and Medical Department consumer issues were among the subjects addressed in a needs assessment effort. Starting with health promotion information tables at residents' orientation week and ending with a "safe summer" send-off at the end of the academic year, at least 1800 students were directly reached by the Health Education Service. The Medical Department's IAP effort was extensive with a total of 57 workshops, attracting 1435 participants. AIDS Aware efforts continue at the high pace established this year, collaborating with the Personnel Office, Student Counseling and the physicians of the Medical Department. In addition to outreach services involving the MIT community at large, the Health Education Service is expanding its presence within the Medical Department, including patient education activities in subspecialty and Inpatient services. The energy, devotion and originality of Ms. Van Ness and her colleagues, Constance Bean and Ms. Gilligan, cannot be over emphasized.

MIT Health Plan

As a result of a successful enrollment period in November, the membership increased to a new high of 8740, the largest level of enrollment that ever has been achieved by the Plan. Forty-three percent of employees now belong to the MITHP, giving us the largest share of the health insurance market at MIT. We anticipate, with the development of the new product, that there will be a further increase of enrollees as well as some shift from the traditional Plan during the first year. The Plan's financial status continues to fall under budget, despite an aging membership and the relatively unabated inflation in healthcare costs. Our positive financial results stem largely from successful management of acute care hospital costs and the use of the Department's Inpatient Service to reduce days in costlier outside facilities. In July of 1987, the management and analysis of Plan finances and enrollment data was strengthened by the hiring of Heather Ryan who has contributed greatly to the Plan's financial stability, and also to the development of the data necessary for the planning of the upcoming new product.

Environmental Medical Service

Under Dr. Alan Ducatman's able direction the Environmental Medical Service has continued to provide outstanding consultation surveillance, and education on the MIT Campus. In the area of laboratory health and safety quality lectures have been provided for students, employees and faculty. Medical surveillance and control over respirator wearers has led to new procedural and engineering outreach to laboratory scientists. The presence of Dr. Charles Billings in the Industrial Hygiene Office has rejuvenated facility planning services, innovative means of doing risk assessment for mixed environments and cooperative efforts towards Campus-wide asbestos abatement. The Radiation Protection Office has been active in a variety of facility areas, including changes at the Linear Accelerator and public health activities on Campus. The Biohazard Assessment Office assisted in the safety planning phases of a new facility at Whitehead Institute, a seminar on health hazards of biotechnology, and assessment of pest control issues through the consultatory efforts of Dr. Alpert. Given the broad range of environmental safety activities which EMS is responsible for it is impressive to be able to record in so many different areas a continuing effort to teach and to problem solve. Much credit should be given to Dr. Ducatman and his staff.

DIRECT PATIENT CARE SERVICES

Ambulatory and Inpatient Services

In the Inpatient Unit, thanks to the leadership of the Unit Coordinator, Maureen Dickey, R.N., we have been isolated from problems of nursing personnel changes. Physical improvements in the Inpatient Unit have been realized as a result of the efforts of individuals like Mrs. Catherine Stratton, and from the generosity of the Gould Fund. The Inpatient nursing staff has found the weekly meetings with Dr. Joseph Brenner of the Psychiatry Service to be most helpful in dealing with psychosocial patient care issues. The Off-hours Clinic visits held constant at approximately 6000 for the year, the majority coming on weekends and weekday evenings. Coverage continues to be provided by a team of nurse practitioners and physicians. At night physicians in the Inpatient Unit provide an emergency consultative resource for the Off-hours Clinic.

Dental Service

Under the able direction of Dr. Cynthia Stevens, the number of patient encounters continued to grow during this year and quality assurance programs have been implemented to assure that the service provided is in the best interest of patient care and efficiency. A major goal that remains for the upcoming year is to provide more services for students.

Pediatric Service

Dr. Barbara O'Pray, Chief of Pediatrics, reports that pediatrics remained very busy with over 8000 visits the past year. It is anticipated that even higher utilization will begin in September when new healthcare legislation, mandating insurance coverage of preventive healthcare for children under the age of 6, becomes activated. Issues of staffing remain critical. An area being explored is the introduction of pre or post work clinical services to allow family members to bring children to the Pediatric Service after work responsibilities are fulfilled.

Psychiatric Service

The Psychiatric Service continues to provide far flung professional inputs into the life of the Institute, providing consultation to many of the committees and offices representing student, faculty and employee interests at MIT. A reduction in length of stay of patients hospitalized with emotional problems was achieved during this past year, facilitated by better communication between MIT and hospital-based psychiatrists. In addition, there has been a greater use of the Inpatient Services at the Medical Department, aided and abetted by staff psychiatry contributions to nursing personnel activities. Alcohol and drug detoxification admissions still represent a significant number of those that occurred this past year. The ambulatory area visits dropped slightly but the total number of patients seen remained about the same. As Dr. Kahne reports, and I quote, "The year has been one of great tension on Campus, resulting from an unusual number of student suicides. The attendant anxieties among the students, faculty, support staff, and professionals in their attempts to cope with the situation certainly influenced the kinds of problems we have had to deal with and often taxed the ingenuity of the psychiatric staff in meeting crisis". It should be mentioned that imaginative, flexible and innovative responses have been undertaken. In addition planning is underway here at MIT and in a consortium of universities that are studying the problem of suicide on campus, sponsored by the Barnard Institute of Columbia University.

Ob/Gyn Service

Increased activity of the obstetrical service has occurred, both in Health Plan and student family participants who have sought obstetrical care at MIT. The number of patients seen for primary and secondary infertility problems has also increased, many of the couples being over the age of 30. The Ob/Gyn Service was very active during IAP with a number of talks on areas such as the menopause, family planning and prepregnancy planning. Nurse practitioner Karen Halvorson has been busy teaching an evening childbirth education course through the Health Education Service. With the hiring of a full-time nurse coordinator and a new medical assistant, Ob/Gyn has begun to upgrade the efficiency of its Service.

Student Health Service

As mentioned earlier in this report, the activities of the Student Health Service have focused on a number of new initiatives, the most significant of which is the assignment of a personal physician to incoming students. The success of that program as noted by student responses in a questionnaire circulated in April 1988, and also the evaluation of our primary providers here in the Department, encourages us to expand the program to the entire Freshman class as well as to the incoming graduate students. It is anticipated that over the next several years we will learn a great deal more from this experience through direct involvement with students as well as an end of year questionnaire. From this information we can be more responsive to the most important needs of the student population here at MIT. Dr. Goldstein's efforts in bringing about this program are greatly appreciated. The Student Health Service has also been involved in a variety of teaching activities, working in conjunction with the Health Education Office and other members of the Medical Department. As part of the Infection Control Committee activities various immunization practices for students have been reviewed and simplified, including surveillance measures and vaccination procedures.

Surgical Service

Dr. Stephen Healey, Chief of the Surgical Service, reports that the Service has been active during this past year and that well over 100 general surgical patients were admitted to our Inpatient Unit following surgery at Mount Auburn Hospital. Approximately 350 minor surgical procedures were completed in the

MIT Medical Department, and infection rate of insignificant proportion. Ambulatory surgical visits and attendance at surgical subspecialty clinics remain active. It is anticipated that additional physician time may be required in ENT and that modifications in the consulting mechanism for orthopedic surgery may result in shorter queues for seeing an orthopedic surgeon. In addition, we look to improve efficiencies in the Sports Clinic activities planned in conjunction with the Athletic Department.

In conclusion, this has been a year of great accomplishment in terms of realizing sought after goals in a variety of areas. Based on inquiries of the Visiting Committee last year an in-depth examination of the financial balance sheet of the Department was undertaken by Linda Rounds, Executive Director. This was summarized and reported to the Medical Management Board and then to the MIT Corporation Executive Committee in September 1987. The clarity of the report and the very positive responses of the Corporation Executive Committee were a testimony to the responsible way that the Medical Department has been conducting its fiscal affairs. It was an impressive example of the outstanding contributions of our Executive Director to the business-fiscal health of the Medical Department. And as we move toward a new product for the MIT Health Plan, and remain sensitive to the needs of the MIT community, we are exploring the feasibility of a satellite clinic in juxtaposition to Lincoln Laboratory in the western suburbs.

ARNOLD N. WEINBERG, M.D.

Fiscal 1988 was the year of solid growth in sales in both the Books and Journals divisions. Overall, dollar sales were up 11 percent and both books and journals produced a modest net after expenses. Foreign sales have continued their dramatic improvement, especially in Europe, where sales posted a 40% gain over last year. In program development, we closed down our European editorial office, established a new program in neurosciences, expanded our program in computer science and artificial intelligence with the addition of a senior editor. We also created the position of Electronic Publishing Coordinator to facilitate the use of author-generated electronic copy for setting type; and inaugurated the use of Macintosh-based system for designing book jackets. As a result of the "completed" Kendall Square and our expanded space, The MIT Press Bookstore sales were up 47% at 400K. After five years of work, we published the monumental George's Bank Atlas, Klotz: The History of Post-Modern Architecture; our first books in neural networks, Anderson: Neural Computing, Foundations of Research, and launched a promising new program with Zone Publications.

We published 164 titles, 129 original publications, and 35 paperbacks reprinted from our own hardcover backlist. In addition, we published 6 separate pieces of software. Unit sales were up 4 percent to 563,000 copies.

Bestsellers from the Fiscal 1988 list included:

McClelland and Rumelhart	Parallel Distributed Processing, Programs and Exercise
Churchland	Matter and Consciousness
Minsky and Papert	Perceptrons Expanded
Chomsky	Language and the Problems of Knowledge
Rumelhart and McClelland	Parallel Distributed Processing, two volumes
Freedman	Little Lisper
Bernauer	Final Foucault
Hershey	Lost Meaning in Architecture
Klotz	History of Postmodern Architecture
Racine	Gardens of Provence
Quinn	Frank Lloyd Wright: Buildings
Wallace	Blasted Allegories
Habermas	Philosophical Discourses of Modernity
Slater	Portraits in Silicon
Robinson	Architecture Transformed
Grimson	AI, 1980 and Beyond

MIT AUTHORS

Allen & Leighton	Advanced Research in VLSI
An, Atkeson, Hollerbach	Model-Based Control of a Robot Manipulator
Barrett	Text, ConText, and HyperText
Canny	The Complexity of Robot Motion Planning
Cartwright	Philosophical Essays
Chomsky	Language and Problems of Knowledge
Cleveland & Bloomfield	Prospects for Peacemaking
Danly & Marx	The Railroad in American Art
Fischer	NBER Macroeconomics Annual 1987
Halle & Vergnaud	An Essay on Stress
Lampe	The Massachusetts Miracle
Minsky & Papert	Perceptrons, expanded edition
Thomson	On Being and Saying

Among the noteworthy books by non-MIT people from our scholarly and professional program were:

Blumenberg	The Genesis of the Copernican World
Dennett	The Intentional Stance
de Sousa	The Rationality of Emotion
Dretske	Explaining Behavior
Emerson	What Model for Europe?
Frenkel & Razin	Fiscal Policies and the World Economy
Helfat	Investment Choices in Industry
Jackendoff	Consciousness and the Computational Mind
Krüger et al.	The Probabilistic Revolution
Lewis & Davis	Domestic and International Banking
Liebersohn	Fate and Utopia in German Sociology
Lycan	Consciousness
MacDougall	Simulating Computer Systems
Mendeloff	The Dilemma of Toxic Substance Regulation
Putnam	Representation and Reality
Schiffer	Remnants of Meaning
Taylor	What Every Engineer Should Know about AI
Thagard	Computational Philosophy of Science
Warren	Nietzsche and Political Thought

New hardcover books for trade and general audiences included:

Flink	The Automobile Age
Hersey	The Lost Meaning of Classical Architecture
Hirschhorn	The Workplace Within
Quinan	Frank Lloyd Wright's Larkin Building
Racine	The Gardens of Provence & the French Riviera
Tanchis	Bruno Munari
Van Zanten	Designing Paris
Weingarden	Louis H. Sullivan: The Banks

Books published primarily as texts included:

Arazi	A Commonsense Approach to the Theory of Error-Correcting Codes
Laffont	The Fundamentals of Public Economics
Lasnik & Uriagereka	A Course in GB Syntax
Lehiste	Lectures on Language Contact
McClelland & Rumelhart	Explorations in Parallel Distributed Processing

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 (Bradford Books); and Charlotte Richie (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, and The American Institute of Graphic Arts.

COMPARATIVE OPERATING RESULTS (in thousands)

	<u>Fiscal Year</u> 1988	<u>Fiscal Year</u> 1987 <u>Actual</u>	<u>Fiscal Year</u> 1986 <u>Actual</u>
Total Net Book Sales	\$ 8,830	\$ 7,941	\$ 6,939
Cost of Sales	<u>3,721</u>	<u>3,408</u>	<u>3,034</u>
Gross Margin on Sales	5,109	4,533	3,905
Other Pub. Income	167	135	333
Bookstore Net	<u>90</u>	<u>40</u>	<u>40</u>
Total Income	5,366	4,708	4,278
Operating Expense	<u>5,292</u>	<u>4,841</u>	<u>4,024</u>
Net Books Division	74	(133)	254
Journals Net	<u>4</u>	<u>(113)</u>	<u>1</u>
	78	(246)	255

The Press received approximately \$50,000 in subventions aiding the publication of five of its titles during the past year. Among the sources of subvention were the J. Paul Getty Trust, the Volkswagen Stiftung, the National Endowment for the Humanities, and Inter Nationes. These grants helped make possible the production of Block/The Utopian Function of Art and Literature, Blumenberg/The Genesis of the Copernican World, Klotz/The History of Postmodern Architecture, Kruger et al./The Probabilistic Revolution, Smith/On Walter Benjamin, and Weingarden/Louis H. Sullivan: The Banks.

Faculty serving on The MIT Press editorial board in 1987-1988 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 chairman of the editorial board.

The MIT Press management board met twice 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 chairman 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 linguistics, economics and philosophy, with the balance of our efforts devoted to publicaion of important works in science, technology and society, and in science and engineering.

BOOK SALES

<u>Customer Type</u>	<u>Fiscal Year 1988</u>	<u>Fiscal Year 1987</u> (in thousands)	<u>Fiscal Year 1986</u>
College Bookstore	\$ 1,531	\$ 1,280	\$ 1,501
Retail Bookstore	1,685	1,440	1,774
Wholesaler/Jobber	1,475	1,420	1,750
College/University Library	75	110	164
Direct Mail	746	520	584
To Individuals	<u>592</u>	<u>500</u>	<u>755</u>
TOTALS	6,206	5,340	6,527

Under the direction of Tom McCorkle, this was another good sales year for the Press. Total sales increased from \$7,940,900 to \$8,830,300, or by about 11 percent. Also encouraging was the growth in units sold -- from 540,616 to 562,340, or about 4 percent.

INTERNATIONAL SALES AND SUBSIDIARY RIGHTS

This year's sharp decrease in the value of the U.S. dollar against other major world currencies made The MIT Press books significantly less expensive for foreign customers. With a vigorous export marketing organization already in place, and with continued strong output of new titles from the Press' publishing program, the result was a 30 percent increase in international sales in Fiscal Year 1988. The only significant sales decline, which was expected, was in Japan. Book purchase in Japan were unusually large in 1987 due to special sales opportunities during that year which were not available this year.

International Book Sales FY 1986 - 1988

	<u>Fiscal Year 1988</u>	<u>Fiscal Year 1987</u>	<u>Fiscal Year 1986</u>
Australasia	\$ 83,100	\$ 63,800	\$ 38,900
Canada	356,100	308,200	272,900
Japan	428,900	520,400	292,100
Rest of Asia/Other	411,500	229,140	197,200
Latin America	26,500	27,700	21,200
UK/Europe	1,361,000	902,200	724,300

The core of the subsidiary rights marketing program is translation rights sales, which are less subject to wide annual fluctuations than are sales to bookclubs. Translation rights income increased by 13 percent this year. Development of a new market showed its first results, as sales or rights to excerpt segments of The MIT Press videotapes brought in almost \$9,000. Future growth of sales in this category will depend on the rate of issuance of new videotapes by the Press.

Subsidiary Rights Income FY 1986 - FY 1988

	<u>Fiscal Year 1988</u>	<u>Fiscal Year 1987</u>	<u>Fiscal Year 1986</u>
Translation Rights	\$ 98,509	\$ 87,449	\$ 36,296
Book Club Rights	46,046	71,924	20,152
Reprint Rights	15,093	14,773	20,555
AudioVisual (new category)	<u>8,726</u>	<u>---</u>	<u>---</u>
	168,374	174,146	77,003

Promotion and Direct Marketing

Under the director of Brooke Stevens, the promotion department had a mixed year in its communications and selling programs.

Direct mail sales for the year were \$587,366, down 21 percent from Fiscal Year 1987. This decrease in sales can be attributed to the absence of books with strong mail order markets sold in Fiscal Year 1987 (these accounted for five additional mailings) and mailing lists that were no longer available to us for the annual clearing sale. Sales were up 11 per cent over Fiscal Year 1986. The press mailed out catalogs and brochures in computer science, cognitive science, economics, architecture, evolutionary theory, philosophy and aesthetics, and a sale catalog (income from the sale declined 61 percent from last year.) The contribution to overhead, however, declined by only 2 percent, which indicates that mailings were more profitable in Fiscal Year 1988.

Text sales promoted through direct mail reached \$1,771,000, a disappointing 4 percent increase in dollar sales over last year. Unit sales (167,719) decreased by 13 percent. This can be attributed to two sources: fewer primary texts this year and unprecedentedly high returns from college bookstores.

The exhibits program, not a traditional source of income, has become a small profit center. In Fiscal Year 1988, sales were \$104,806, a 7.6 percent increase over last year. There was a 43.8 percent increase in the number of meetings attended and a 26.5 percent increase in costs. The net to the Press was \$75,000.

Advertisements for The MIT Press books appeared in over 261 trade and scholarly journals and magazines, a 16 percent increase in insertions over last year, as we launched the distribution of Zone Books. We also began in-house production of ads on the MacIntosh.

In Publicity, The MIT Press books received 1,045 reviews, 86 of these major reviews, with art and architecture titles receiving the most attention. We garnered seven reviews each in the Los Angeles and New York Times Book Reviews. Attention to MIT Press titles also came from Byte, Classroom Computer Learning, Science, Nature, Smithsonian, The New Republic, The Village Voice, Fortune, The Boston Globe, The Wall Street Journal, Progressive Architecture, The New Yorker, House & Garden and Newsweek.

JOURNALS

The journals division had gross sales of 1.93 million, a seven percent increase over last year. Two publications were added to the program in 1988: Computational Linguistics, published for the Association for Computational Linguistics, published for the Association for Computational Linguistics, edited by James Allen, University of Rochester; Design Issues, published semi-annually for the University of Illinois, Chicago, edited by Victor Margolin.

There are currently twenty journals in the program. The others are: Assemblage, Computer Music Journal, Design Quarterly, The Drama Review, Journal of Interdisciplinary History, International Organization, International Security, Linguistic Inquiry, Materials and Processing Report, Mimar, NBER Macroeconomics Annual, October, Places, The Quarterly Journal of Economics, The International Journal of Robotics Reserach, The International Journal of Supercomputer Applications, Tax Policy and the Economy, and The Washington Quarterly.

October received a grant of \$20,000 from the Getty Trust to publish a special issue of Marcel Broodthaers; Places receive \$15,000 from the NEA for a series of articles on design in the contemporary city; Assemblage received a grant of \$4,000 from the MAssachusetts Council on the Arts and Humanities to support publication of two translated works and two architectural projects.

The International Journal of Supercomputer Applications was recognized as the "best new journal in science and technology" by the Association of American Publishers; Assemblage received the same recognition as the best new journal in the humanities.

FRANK URBANOWSKI

Personnel Office

In addition to the normal ongoing responsibilities of the office, major effort was required to address new regulations. The Immigration and Reform Act passed by Congress requires employers to verify the legal status of all employees hired after November 6, 1986. Compliance with this law was achieved with considerable help from department administrative officers and members of the International Visitors Office.

The Internal Revenue Service issued new laws that impacted on the tax status of those receiving benefits under the Tuition Assistance and Children's Scholarship Plans. Legal counsel has been working closely with us this year in interpretation of new and revised laws effecting pension plans.

A Department of Labor review was particularly time consuming in that a greater level of data, in a different format, was requested.

The strategic review of benefits continues with much of our time being dedicated to a major review of pension plans.

A reorganization of responsibility took place in late June with the appointment of a Manager of Benefits. Responsibility for Compensation, which included Wage and Salary and Benefits, has been admirably carried by Kerry B. Wilson since 1981. With the appointment of Deborah A. Kelley to the position of Manager of Benefits, Kerry will continue to be responsible for Wage and Salary administration and will work more closely with the Director on projects both within the Personnel Office and in the Community. Kerry's dedication and creative thinking in the area of benefits has been outstanding. We are fortunate that we can still avail ourselves of his expertise as we move ahead.

There were several staffing changes during the year. Nancy Collins was promoted from an Administrative Assistant position in our office to the new position of Employment Recruiter. Maureen C. Wolfe and Cynthia L. Froeber joined the staff as Personnel Officers. Ms. Froeber was previously an Administrative Assistant in the Department of Chemical Engineering. Ms. Oveta O. Perry left to assume a position in the Center for Cancer Research. Joanne DeSiato left the Child Care Office and was replaced by Rae A. Goodell. Ms. Goodell was previously a Lecturer in the Writing Program.

JOAN F. RICE

PERSONNEL DEVELOPMENT

During 1987 - 1988, a total of 4,500 employees participated in Personnel sponsored programs including in-house training and development opportunities; presentations offered within laboratories, departments, and centers; and sponsorship for outside educational opportunities through the Tuition Assistance Program.

A wide variety of training and development opportunities were presented at the Institute. Twenty-two new or revised programs were added addressing job-related and career-related skills with special attention to supervisory, communication, and stress management skills. In total, 53 different training programs were offered during the year and many of them were repeated several times.

Many programs were custom-tailored for and presented in different departments at the Institute. Topics in these programs ranged from communicating about performance and career development, to time and stress management.

Many of the presenters in the programs are members of the MIT community who continue to provide their time and expertise to the training effort.

SUSAN WARSHAUER

COMPENSATION OFFICE

Wage and Salary Administration

The Compensation Office worked to provide fair and equitable salary administration across the Institute through the annual review process, and in the review and analysis of individual salary increase and promotion recommendations submitted by department supervisors throughout the year. Approximately 8,300 individuals received consideration for salary adjustment this year, both on campus and at Lincoln Laboratory, through these individual and annual merit reviews.

Allocations for merit reviews are determined through 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 Administrative and Professional Salary Survey, and two Boston-area Support Staff salary surveys.

Twenty-five universities participated in MIT's 1987 - 1988 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 thirteen area employers participated in MIT's Fall 1987 Administrative and Professional Salary Survey. This survey, now in its thirteenth year, surveys 40 benchmark positions on the administrative staff for comparison of average salaries, salary ranges, and similarity of organizational structure.

Difficulties in recruiting qualified support prompted us to make a major effort this year during the Support Staff annual review to adjust significantly our Support Staff ranges, and make available to department additional allocations to alleviate compression of salaries of current employees resulting from higher starting salaries.

We have actively participated in a new review of Support Staff position descriptions and discussion of salary range structure with members of the Working Group on Support Staff issues.

A total of 106 requests for reclassification on the Administrative Staff were received during the year: 60 requests to assess newly created positions; 11 promotional requests for individuals moving from Support Staff; 18 requests to reevaluate existing positions and their salary ranges; and 17 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.

Benefits Administration

The Compensation Office implemented several new benefit plans during the last year including a dental plan, offered through Delta Dental Plan of Massachusetts, and a new alternative Blue Cross and Blue Shield option which provides protection from financial hardship in the case of catastrophic illness at less than half the cost of the original Blue Cross and Blue Shield plan. In addition, the Institute also offered a new life insurance plan which provides \$50,000 of coverage to full-time employees at no cost and allows employees to purchase additional coverage in multiples of 1 to 5 times salary at age related rates.

We developed a program to communicate these changes which included eight open meetings, four benefit fairs on Campus and at Lincoln Laboratory, a supplement to Tech Talk, and other written materials including payroll stuffers, and a booklet containing the highlights of the new plans. We designed a common enrollment form covering health, dental, and life insurance, and the Flexible Reimbursement Account Plan to facilitate the application process during the annual open enrollment period. We also wrote handbooks summarizing plan details for the three new plans and rewrote five other handbooks which were distributed to appropriate members of the MIT community.

The benefits orientation program was completely revised and a slide show was developed to illustrate key aspects of the benefit plans. Ninety-three orientation sessions were attended by 825 new faculty, academic, sponsored research, administrative staff, and support and service staff members.

We also responded to over 40,000 telephone calls and to the 4,000 faculty and staff who visited the office during the year.

Improvements in MIT's benefit plans and changes in the federal tax laws effecting the Tuition Assistance and Children's Scholarship Plan dominated the activity in the Benefits Systems & Records Area this last year. Much effort was put into modifying existing procedures and computer systems. Over 800 employees used the Tuition Assistance plan and 730 children of MIT employees benefitted from the Children's Scholarship Plan in the last year.

In addition, this year's Open Enrollment period was a particularly busy one as we asked each eligible MIT employee to return an enrollment form. Over 90% responded for a total of about 6,000 forms processed for the period.

The Compensation Office counselled some 180 retirees on an individual basis this year. Approximately 100 death and disability claims were processed as well.

In the past, the Compensation Office had offered a five-part pre-retirement planning seminar series which spanned several weeks. In the Spring of 1988 the Compensation Office introduced a revised two-day program which included discussions pertaining to legal awareness, health and nutrition, financial planning, MIT benefits before and after retirement, fitness and exercise, and Social Security information. All employees age 55 or older with 10 years of service were invited to attend the seminar. Spouses, relatives, or friends of the employees were also encouraged to attend. Nearly 140 employees and guests participated in the seminar this Spring.

KERRY B. WILSON

FACULTY AND STAFF INFORMATION SERVICES

Faculty and Staff Information Services has the responsibility to acquire, maintain, and provide employment information about faculty, staff, and other persons affiliated with MIT and to insure the currency, privacy, and accuracy of this information.

The office processed more than 14,000 appointments and changes, an increase over last year's activity. In addition, the office continued its role in the production of the staff telephone directory and the processing of the various salary reviews.

In the past year, there was a substantial increase in the demand for benefits data including programs to assist in the analysis of the new benefit programs as well as the open enrollment processing. Major modifications to the Personnel databases were implemented in preparation for the new dental and life insurance programs. Other computer related accomplishments were the conversions of several hundred Easytrieve Programs which is due to the removal of support for Easytrieve and other VSI jobs.

The introduction of personal computers into the daily work lives of Personnel Offices was achieved with great success. Initial training and continued assistance are given by members of the FASIS staff.

CLAIRE L. PAULDING

LABOR RELATIONS

Fiscal 1988 concluded with the new two-year labor/management Agreements in place. The Director of Personnel served as the chief spokesperson for the contract negotiations with the two Service Employee's International Union Agreements for the campus and the Lincoln Laboratory. The Manager of Labor Relations was the chief spokesperson for the Institute wide negotiations with the Research, Development and Technical Employees Union. These agreements provided for major new benefit plans covering dental care and life insurance as well as expanded health care options and improved past service benefits under the current retirement plan. The negotiations were prolonged over a five month period because of the difficulties of the parties coming to agreement on the new and improved benefits for Service Staff Employees.

The Campus Police Association continued in fiscal 1988 attempting to negotiate a new agreement in the face of the Institute's decision to put the two year offer of May 1987 into effect on October 5, 1987. The Officers continued to work without incident. In December 1987, the Manager of Labor Relations offered the Association a new proposal for a three year (1986, 1987, and 1988) Agreement which not only included a substantial wage increase for the third year (with retroactivity for 1986 and part of 1987) but also the new and improved benefits given to other unions. As of May 1988, the Association Officials and the membership rejected this offer twice.

In June, the Institute informed the Association Officials that unless the offer was accepted prior to the 30th it would stand withdrawn and retroactively would not be in any future negotiation for a new contract. The membership voted to accept the offer and the Officials of the Association signed the new agreement on June 24, 1988.

The grievance and arbitration work load remains constant but with a reduced number of formal complaints. The issue of student involvement with unions has surfaced for the first time in many years. We have had our first formal charge by a female student who alleged sex harassment by Service Staff Employees who are members of the Research, Development and Technical Employees Union. The issue is currently before an arbitrator. This same union is attempting to circumvent a professor's judgement on disciplining an employee for failure to perform the duties and responsibilities of his job in a satisfactory manner by attempting to subpoena students who may have complained about the employee's work. This issue is also presently before an arbitrator.

Currently we are negotiating a new labor agreement with the International Union of Plant Protection Employees Local #14 that represents guard employees at the Lincoln Laboratory. We look forward to a reasoned solution agreed to with the elected representatives of these employees in the near future.

JAMES F. FANDEL

PERSONNEL SERVICES AND EMPLOYMENT

Personnel Services has the responsibility for the development and interpretation of policies and procedures, and for the coordination of personnel and employment matters.

The primary challenges faced by Personnel Officers have been in three areas. The first area of service needed has been to assist departments toward better allocation and utilization of human resources to meet the challenges presented by new work demands in the context of a rapidly changing technology. A second challenge has been to coordinate and facilitate bringing about an improved compatibility between organization goals and individual employee goals. The third area relates to finding more creative and effective ways to resolve personnel problems in order to increase effective supervision and employee morale. Personnel Officers have endeavored to meet these challenges by working closely with supervisors and managers providing them with better resources and guidance based on their knowledge obtained through diversified professional experience and educational endeavors. It is expected that the challenges stated will continue to be of great importance in personnel work for several years into the future.

EMPLOYMENT ACTIVITY

Employment recruitment, particularly for Support Staff positions, continues to be a complex activity which presents great challenges to MIT departments. Because the pool of applicants is small, maintaining a continuous flow of qualified applicants has remained difficult. More people are making use of temporary assignments to find work environments that offer the best opportunities for good benefits and career growth. Another factor related to this is the fact that new employment agencies are starting up at an increasing rate. The result of this increase is that individuals seeking regular employment are utilizing agencies for assistance in finding jobs resulting in organizations being required to pay high fees, in addition to other recruitment costs, to obtain qualified people to fill their positions. The Personnel Office added a Recruiter to our staff and we have developed new sources of qualified applicants through a very broad outreach program. We have also worked with departments to create new ways of advertising which include better marketing of the advantages of a career at MIT and have used new advertising formats which have been very effective. We will continue to utilize the recruitment efforts that have been successful and will be designing new activities to meet our recruitment needs.

The past year 1,176 positions were posted. Personnel Staff interviewed 832 applicants referring approximately 75% to departments for consideration. The total applicant pool was 7,540 from which 916 were hired. In addition, 202 employees transferred into new positions within the Institute.

SUSAN P. GASKELL

CHILD CARE

During the year 1987-88 the Child Care Office experienced a 50% increase in the number of referrals provided to MIT families seeking child care or school programs for children. Child Care Office brochures were redesigned and began being distributed to all new employees through the Personnel Office; this wider distribution may have increased community awareness of Office services.

Of the 268 families who contacted the Child Care Office in 1987-88, 214 were seeking some type of care for children under two years nine months of age, including 160 seeking infant care (under 15 months), and 54 seeking child care or preschool for children over two years nine months. Technology Children's Center, the center-based preschool program on campus, provides the initial contact for many additional families with children over two years nine months; it continues to serve approximately 100 preschoolers.

Computerization of referral data this year has also improved data collection, and has allowed for better tracking of search outcomes and improved the detail and quality of information available to parents on area programs. The availability of quality, affordable child care continues to be uneven, with parents

experiencing the most difficulty locating infant care and short-term, vacation week or sick-child care. The number of family day care openings on campus, which are used primarily by parents searching for infant care, has been reduced by new delays in the Office for Children licensing process as well as by the Office for Children's freeze on licensing above the ground floor of the Westgate lowrise complex; efforts to resolve the Westgate issue continue.

Special programs and activities this year have included: continuation of Children's Swim classes; IAP events for children and parents; family day care training workshops and ESL classes; campus-wide presentations including a lecture by Dr. T. Berry Brazelton on "Working and Caring", co-sponsored with the Women's Forum, and a panel discussion on parental leave co-sponsored with Women's Studies; expansion of the Parent Lending Library; initiation of group discussions every other month entitled "Child Care Discussions for Parents-to-Be" to provide group orientation and some opportunity for parent networking for first-time parents and those contemplating parenthood; and appointment as staff to the Faculty Committee on Family and Work.

Supervisorship of the Office has moved from the Director of Technology Children's Center to the Director of Personnel. Luise Flavin, director of Technology Children's Center for eleven years and former supervisor of the Child Care Office, left her position in August, 1987. Joanne DeSiato left her position as Child Care Coordinator in October; Kathy Simons became Child Care Administrator (formerly co-Coordinator) and Rae Goodell joined the Office staff as Child Care Coordinator. A temporary full-time support staff position was approved to replace the part-time use of student assistants, in order to reduce turnover and increase support for the Office as it assumes responsibility for staffing the Faculty Committee on Family and Work.

At Technology Children's Center, Priscilla Donham left her position as head-teacher of the Westgate Nursery School after 19 years. The TCC board adopted a new Parental Leave policy offering 8 weeks paid leave to TCC employees; and reconstruction of the Westgate playground was jointly conducted by TCC and MIT.

KATHY L. SIMONS

Public Relations Services

This was the year of the three "C"s for the Public Relations Services, as we concentrated on Campaign Support, Community Relations, and Computers.

Campaign Support. Virtually every area in our department was involved extensively in support of MIT's *Campaign for the future*, which was officially launched in October 1987 with three days of symposia, press conferences, gala dinners, and alumni events on campus. PRS staff worked with colleagues in Resource Development and in the Alumni Association in the planning and execution of major Campaign kickoff events in Cambridge and New York; participated in ongoing Campaign communications policy and planning; designed and produced Campaign publications; and managing increased public relations activity.

While the department will continue to support the Campaign, particularly in the areas of communications and publications, the Director of Special Events and the Information Center, Mary L. Morrissey, will be able to devote more of her time in the coming year to planning and implementation of campus-wide systems for disseminating information about MIT programs and activities. This will be especially timely as the renovated Student Center opens with its own information booth and as Kendall Square becomes increasingly important as a gateway to the campus.

Community Relations (internal and external). In a year loaded with good news and bad news, the News Office did an outstanding job garnering record publicity for good news, and handling bad news with intelligence and integrity. Inside MIT, there was more open discussion in the pages of *Tech Talk* of difficult issues (such as the decision to close the Department of Applied Biological Sciences). Community events such as Commencement, several of the Campaign kickoff activities, and especially the Johnson Festivities (celebrating the naming of the Athletics Center in honor of Howard W. Johnson, Honorary Chairman of the Corporation) brought faculty, students, and staff together as planners and participants in a way that reinforced the sense of MIT as a community, not just a place to study or work.

In the coming year, a major goal in the realm of internal community relations is to find ways to open channels of communication so as to enhance the quality of life for students, faculty and staff, and create a greater mutual understanding or awareness about issues of concern to the people who work and study here. Examples of such steps include the following: Have *Tech Talk* become a vehicle for discussing broader issues of interest to students, faculty, and staff, and for showing the administration's concern about such issues. Develop recommendations from the International Issues Group to improve the quality of life for MIT's international community. Plan events (such as the Johnson Games) that bring together people from throughout the MIT community -- for work or play -- but in ways that cut across organizational and demographic lines.

Computers. Every office in the area made great strides in the computer arena: desk top publishing, computer aided design, data base creation all gained a foothold. The new technologies are not only saving time and money in the publishing field, but in the area of design, for example, they are enhancing creativity. On the other hand, some ask whether our ability to do things faster, more efficiently, and more fully has the effect of stepping up the metabolism of the place.

This question, however, does not stop our plans to continue developing the use of computers in communications, publications, and design. Examples of current plans include the following: Typeset the coming year's catalogue entirely with desk top publishing system. Develop a computer-based information system for use by Admissions, the Student Center, and the Information Center. Develop computer-based media lists and utilize computer communications with MIT departments as well as with outside media.

Overall, this past year has been remarkable -- in terms of workload and in the intensity (and sometimes difficulty) of issues to deal with, to be sure -- but remarkable in terms of the dedication, energy, time, and skill which the members of the department devoted to their responsibilities. It is not possible to thank them enough for all that they do to create at MIT a sense of community and pride.

Kathryn W. Lombardi

DESIGN SERVICES

The Office of Design Services continues to support the communications efforts of MIT by designing and managing the production of publications for departments and offices throughout the Institute. Among the areas receiving major assistance from the office during the past year were the Corporation, Resource Development, the School of Engineering, the Sloan School of Management, the Special Summer Programs, and a wide range of special events and conferences coordinated by the Information Center. Included among special events this year were the Dedication of the Johnson Athletics Center, and the Centennial Celebration of the Department of Materials Science and Engineering, and many activities celebrating the launch of MIT's *Campaign for the future*.

Overall the office undertook 281 graphic design and publishing projects in 1987-88.

Jacqueline Casey's work was featured in the exhibition "Ten Pivotal Women in Graphic Design" in Chicago. This show covered a period of 100 years. Her work was also included in two books: "30 Centuries of Graphic Design" by James Craig, Watson-Guptill, New York, 1988 and "Women in Design" by Liz McQuiston, Rizzoli International, New York, 1988. She received the 1988 William J. Gunn Award from the Creative Club of Boston. This award is given to those "who had proven an integrity of purpose, inspiring others to realize their potential beyond the material aspects of their professional ambitions."

Celia Metcalf has been promoted to Associate Director in recognition of her leadership and initiative. In this new position, Celia will continue as a senior graphic designer and will take on responsibilities such as coordination of new clients, the continuation of computer-aided design systems, and supervision of any free-lance assignments that may arise. One of her designs received an award from the Creative Club of Boston.

Jacqueline S. Casey

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 the coordinating of Institute dedications, meetings, and conferences.

Public Relations and Information

As in the past, 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 the MIT Community; distributes over 43,000 pamphlets, brochures, guides, and catalogues; and maintains records and publishes a *Tech Talk* supplement describing and listing memberships of faculty and presidential committees. The tour guide captain, David Kramer, '88, who served both as tour guide and captain for 3 1/2 years received his SB degree in Humanities and Social Science at the Commencement Exercises this past May. He was very committed and dependable and we wish him the best of luck and success. Under Dave's scheduling, there were over 8,850 visitors given tours by 30 of our student staff. Toby Sanders, '90, and Jennie Kwo, G, were full-time guides during the summer months. They were spirited, conscientious, and knowledgeable on MIT programs and history. As public relations representatives, they were outstanding. We expect that there will be many prospective students applying for admission, judging from how visitors responded to them. Under the very able and guiding hand of Lillian Whelpley, arrangements were made for 26 delegates and 4 greetings to be sent to other universities' inaugural ceremonies.

International Visitors Office

The big news in 1987-88 was the computerization of our data base. Data were input all summer and we worked throughout the year on bugs and adjusted records. Minor modifications are likely to continue for some time but our basic program is very good and we are pleased and excited with our progress in less than a year. Reports that could only be done annually because of time can be done easily any time now. During summer, Douglas O'Roark, '89, input data into the computer and helped with the transition. In addition, we also owe much to Scott Thorne of Information Services, who developed the computer program and worked patiently with the office through the year as changes were made.

Visas. What can we say that we have not said before? They were numerous and required close attention. A number of people had real and unusual problems, others thought they did. A lot of advising and hand holding goes on as people become impatient and eager to put immigration behind them.

An area of growing concern is the narrow range of visa options available to students and scholars from the People's Republic of China. With 129 Chinese scholars at MIT, some of whom want to stay longer than their visas permit, this has been, and will be, an area of interest to many.

Some applications took longer than usual at the Immigration Service as legalization and other fallout from the Immigration Reform and Control Act of 1986 took priority over routine matters. Delays with labor certifications lengthened to 9 months.

International Issues Group. The IIG, led by Dean Shirley McBay, continued to meet throughout the year. Questionnaires were developed for international students and tabulating the results will continue into 1988-89. An earlier survey of departments, laboratories, and centers was done in the summer of 1987. The long-term expectations of the group are to make recommendations to the Administration that we hope will improve the quality of life for international students and scholars on campus. Response to the student questionnaires has been high (over 40 percent). Comments by students have been frank and illuminating about what they like and do not like about their experience at MIT and how they would improve it.

Conference Services

Despite the shutdown of the Student Center for renovations (with a subsequent loss of meeting space and dining facilities), the Conference Services Office managed the logistical arrangements of 15 on-campus conferences which brought 3,700 visitors to the campus. The Massachusetts Special Olympics returned for their Summer Games; more than 2,000 spectators viewed the competition which drew more than 1,300 athletes.

In addition to conference coordination, this office provided logistical support to the Campaign Kickoff events in October and December and to the Johnson Games in April. Arrangements were also made for 100 on-campus recruitment presentations in conjunction with the Office of Career Services and Preprofessional Advising.

Special Events

This past academic year was a banner year for special events, which started and ended amid planning, excitement, cheers, and celebration. The director was kept quite busy working with various offices on planning and executing events which included: Campaign Kickoffs in Cambridge and New York; the National Alumni Conference; Killian Hall Dedication; Johnson Athletics Center Dedication and Festivities; Killian Memorial Service; and the Killian Lectures.

As always, a highlight of the year was Commencement, which was held on a beautiful, sunny day. Parents, families, friends, and faculty watched as 1,835 students received 2,055 degrees. A. Bartlett Giamatti, President of the National League of Professional Baseball Clubs and former President of Yale University, was the guest speaker. Thirty-one members of our 50-year class marched in the formal procession, carrying the Class of 1938 banner. After the Commencement exercises, there was a joyous, celebratory reception in the areas surrounding McDermott Court where Professor Samuel J. Keyser, Associate Provost, led the Intermission Trio Plus in some rousing music. Jonathan Monsarrat, '89, volunteered to don the beaver costume and pranced, danced, and posed for many pictures which delighted children and amused adults.

Personnel

We welcome new members of our office -- Jeanne Repec who transferred from the Medical Department to work in the Conference Services Office and Jennifer Stephens whose invaluable support and knowledge, as former director of the international office at Harvard University, is being utilized as a consultant for one day per week in the International Visitors Office -- and we said good bye to Barbara Potter who transferred to the Anthropology and Archaeology Section. Kathleen Barrett celebrated 25 years of service to the Institute and the Information Center, and was awarded the Gordon Y Billard Award for recognition of outstanding merit. Special salutes to Virginia Lyons, head of the International Visitors Office, whose valued expertise is recognized both by MIT and the Immigration Service; Gayle Fitzgerald, manager of Conference Services, whose personal commitment to excellence results in a successful and thriving Service; Lillian Whelpley who is the H-1 expert and fields applications from various exchange agencies with skill and in addition has surmounted many challenges and obstacles programming the faculty preference questionnaire of committees onto a computer-based system; Marie Seamon whose conscientious dedication serves the Conferences Services Office well; Terri Priest who coordinates all short-term international visitors, makes sure the student guides are well trained, and whose organizational skills and photography are appreciated; Donald Ferland, valued assistant to the director, who very capably manages a heavy workload with calmness and a sense of humor; and Tara Dowling, who along with her computer skills, has become increasingly knowledgeable in immigration issues and problems.

Objectives for the Coming Year

The Center's primary objectives for the coming year are to: develop an information network using a computer-based system; work with the International Issues Group in developing good recommendations to improve services and the quality of life for international scholars and students; form a communications group of managers in the housing, food service, and other service areas to discuss issues and implement policies of common concern to those offices supporting conferences and major events.

Mary L. Morrissey

NEWS OFFICE

A recipe for publicity: Take one myth 3,500 years old. Combine it with a beautiful state-of-the-technological-art airplane, built by MIT students and faculty, with wings of 112 feet and weight of just 68.5 pounds. Prepare for three years. Add five superb athletes ready to pedal it solo across 72.5 miles of the Aegean Sea to a world record for human-powered aircraft. Pour in four liters of a special energy-restoring drink. Add a million dollars in corporate, institutional and government money, the Greek Coast Guard and Air Force and various other Ministries. Season with scores of journalists and citizens of Crete waiting patiently for 24 days for the right winds.

The result -- a spectacular flight creating millions of dollars worth of national and international publicity for MIT's *The Daedalus Project*. The event demonstrated once again the artistry and beauty that exists at the edge of technology.

The MIT News Office was happy to provide some of the public relations assistance to the Department of Aeronautics and Astronautics' project, headed by Dr. John Langford, a four-degree MIT alumnus. The 36-person project culminated in the April 23 flight from Crete to Santorini, another Greek island. Veterans of the MIT News Office marvelled at the ongoing attention the project received while it built, tested, and flew three human-powered airplanes over a two-year period.

The Daedalus Project was unquestionably the publicity high point in an academic year which included two Nobel Prize winners for MIT, Professors Robert M. Solow in economics and Susumu Tonegawa in medicine or physiology. Other major news events which brought credit to MIT were a biological breakthrough that was hailed as "The Second Genetic Code"; national and international recognition of MIT as the "Engine for the Economy" in connection with *The Campaign for the future*; the MIT Press' book, "The Massachusetts Miracle"; and the success of MIT's automotive wizardry in the solar-powered car raced in Switzerland and Australia. Another major news event -- a sad one -- was the death of former MIT President James R. Killian, Jr.

The year also had its bad publicity. The homeless people who camped on MIT's University Park as part of a protest of many years were unsuccessful in stopping the development of University Park, which includes 400 housing units within its 2.3 million feet of development on a 217-acre site. The project, being developed by Forest City Development on land owned by MIT, finally received City Council approval. However, the photographs of MIT police arresting homeless persons was not the outcome that MIT sought when it patiently allowed the homeless to camp for more than a month on the property. Two suicides and another student death in autumn, followed by a third suicide in spring, brought journalists to the campus questioning whether MIT had a greater-than-average rate of suicide. It doesn't, but that is of little solace to the grieving families, friends, colleagues and teachers of the students who died.

The News Office significantly increased its level of science publicity through the efforts of our chief science writer, Dr. Eugene F. Mallove, '69. Another addition to the staff, late in the year, was Elizabeth Thomson, assistant editor of *Tech Talk*. She replaced Paulette Boudreaux, who moved to California last September. The News Office staff throughout 1987-88 were Associate Director Robert DiIorio, Assistant Directors China Altman, Charles Ball, Donna Coveney and Joanne Miller, the Editor of *Tech Talk*; Administrative Secretary Joy King; Senior Secretary Lynn Heinemann and Receptionist Mary Thompson Galindo, who got married in the spring.

Tech Talk

The weekly newspaper, *Tech Talk*, was issued 38 times, including a special 12-page edition to commemorate the launching of the *Campaign for the future*. The special issue was prepared by the staff of the Office of Communications in Resource Development. The other 37 issues were under the leadership of Joanne Miller. Altogether there were 300 pages of *Tech Talk*. In addition, each regular issue carried the

section, Positions Available, listing non-academic job openings at MIT. A publication of Information Services, *i/s*, was published nine times in the first issue of each month during the academic year. Other supplements included Benefits Choices for 1988, The Report of the President, and Committees of the Institute. The Independent Activities Period publication, IAP Timetable, was published four times in *Tech Talk* as an adjunct to the Institute Calendar in December and January.

The regular pages of *Tech Talk* featured an Arts Page regularly for the first time, with editorial leadership by China Altman and graphic design by Celia W. Metcalf of Design Services.

In May, *Tech Talk* received a long-desired second class mailing permit from the U.S. Postal Service. This is expected to result in faster delivery to some 560 subscribers as well as 2,000 retired employees.

Computers and Space

A modern photographic darkroom was completed during the year, allowing the News Office to broaden its photographic coverage of the Institute.

Plans for a new computer network are nearing completion as this report is prepared. The flexible system will streamline *Tech Talk* production, allow internal communication, and make our press release effort more effective.

Kenneth D. Campbell

COMMUNICATIONS OFFICE

The Communications Office continued to produce its cyclical series of publications for the Institute, as well as further plans for producing camera-ready copy in house with its new computer capabilities.

The fall proved to be very busy with the publication and distribution of the *Courses and Degree Programs* catalogue, and subsequent production work on the large and small editions of the *Report of the Treasurer* and similar editions of the *Report of the President*. *Tech Talk* supplement issues prepared by the Office included a Financial History report for the Vice President of Financial Operations (29 October 1987), Dr. Gray's annual report to the MIT Community (11 November 1987), and the Committees of the Institute listing (18 November 1987).

Student Telephone Directory production went especially well this year with the new directory publishing company, located in North Carolina. The company is responsible for production of all typesetting and printing of the directory, as well as soliciting area vendors to purchase advertising space in the back of the directory. Revenue generated from the sale of ad space pays for *Directory* publication, saving the Institute more than \$10,000. The project succeeded so well that the Office will help coordinate production of the *Staff Telephone Directory* this fall for the Personnel Office through the same company.

During the winter, the Office produced camera-ready copy in house for the 1988 edition of the *Summer Session Catalogue* directly from its DEC/VAXstation 2000 computer and Interleaf publishing software, resulting in overall savings of production time and professional typesetting costs. Also during this time, the staff began to input into the computer material from other Office publications slated for typesetting production from a laser printer. For the 1989-90 edition of the *Courses and Degree Programs* catalogue, a consultant was hired to design a database structure for the more complex portions of the book — notably the Degree Requirements and Subjects Descriptions chapters — in order to simplify transition of typesetting the entire catalogue from off campus to in-house.

I want to express a special note of thanks to Nancy Ferrari, who is the Editor and Production Manager for the Office. During the past year, she has provided excellent professional support to all Office projects, and has developed and implemented new ideas to help make our work more efficient. Her hard work and dedication to the job could not be left unnoticed.

Personnel Changes

Margery Wilson was hired in the fall as Administrative Staff Assistant to help support the Editor and Production Manager in day-to-day operations. She left during this past summer to pursue a family career. A new Editorial Assistant will be hired for the coming year.

MARK WILSON

Quarter Century Club

The MIT Quarter Century Club membership now totals over 2100, with each member having served the Institute for more than 25 years. At the annual meeting, which was held in March, 111 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 well received and may be added as an annual event. The staff of the Club provides administrative and logistical support to the Institute's United Way campaign, which, for the first time, went over the quarter million dollar level to \$252,351., which represented 97 percent of the \$260,000. goal. The Institute Retirement Dinner is organized and administered by the staff. June ceremonies were held for 154 retiring employees.

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 56 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 eight different companies, a total of 32 trips to various destinations worldwide was offered with most of them including lecturers from various research centers or co-sponsoring universities. A semi-annual bulletin for repeat passengers was also inaugurated with a strong response from the recipients.

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. The staff of the Club consists of Ann P. Brazier, manager, and three assistants, M. Frances Daly, Nanci Drago and Diane Tavitian.

JAMES J. FANDEL

Secondary Technical Education Project

After careful review and evaluation, it was decided that MIT would not renew its contract with the Boston School Department. For the past 14 years, MIT has provided services to students, faculty and parents at the Mario Umana High School of Science and Technology, focusing on areas of Science, Technology, and Writing. The School Department has now refocused its educational priorities in areas where MIT has little or no expertise.

The Institute will continue to provide assistance to the Cambridge Partnership for Public Education, Inc. This is a collaborative effort between major businesses, colleges/universities, and the school department to improve the educational opportunities for all students in Cambridge. MIT spearheads this effort by donating 25 percent of the Executive Director's salary, as well as office space and overhead.

The Massachusetts Department of Education congratulated the Partnership for its excellent work and awarded it a citation for "Noteworthy Partnership."

The Commissioner of Education has appointed Executive Director, Alan Dyson, to the state-wide Extended Committee for Industry-Education Partnerships which is charged with the responsibility of encouraging close collaboration between the business sector and the public schools of the Commonwealth.

1987-88 HIGHLIGHTS

Mario Umana High School

The Eighth Grade On-campus Science Program, conducted at the MIT Museum, consisted of a series of workshops using hands-on exploration in a variety of projects aimed at generating interest in science and technology.

The on-campus MIT/Umana Writing Program proved to be most successful, with students demonstrating vast improvement in writing skills. Out of this effort, a student newspaper developed which produced a staff of talented writers. Each year, both state and national awards were received by the school's editors.

The expansion of the Medical Technology Program at Umana provided student employment at the East Boston Community Health Center.

Most of the students, who participated in the MIT programs, received awards and scholarships at the high school graduation ceremony which was held at Kresge Auditorium. A reception for students, guests and faculty followed the program.

Cambridge Partnership for Public Education

Project R.I.C.H. (Reading Improvement with Computer Help) is a program designed to improve reading skills.

The Mini-Grant Program encourages teachers to design an innovative curriculum for students.

A highly successful Newspaper in Education program aided communication skills between children and parents who do not speak English as a first language.

A Mentors' Program at the Achievement School was provided with assistance from MIT students.

Cambridge Rindge and Latin School students attended the Bentley College Business Week.

A National Science Foundation grant was awarded to encourage middle school girls in an interest in science.

Project Bridge is a program designed to help employees, who take early retirement, become teachers in science and math and to bring teachers into labs to work with scientists.

ALAN DYSON
DOROTHY MAC DOUGALL

Office of the Secretary of the Corporation

This report summarizes the activities and the changes in membership over the past year of the Institute's governing body. The Secretary of the Corporation serves as the Corporation's Recording Officer and as joint signatory with the President in the awarding of the academic degrees of the Institute. The Office of the Secretary of the Corporation is responsible primarily for the four quarterly meetings of the board, the Visiting Committee meetings, and procedures associated with members joining or retiring from the trustee body. It also stands ready, as the need arises, to assist individual Corporation members in the execution of their trustee responsibilities and to support building dedications and other special MIT events.

CORPORATION MEMBERSHIP

At the year's end, Corporation membership consisted of 75 Active Members (43 Term Members, 24 Life Members, and 8 Ex Officio), and 21 Life Members Emeriti. The total of 96 members is the same as at the close of the 1986-87 academic year, but there are now 75 active members as contrasted with 72 a year ago.

Completion of Service

On June 30, 1988, the following four members completed their designated terms of service: W. H. Krome George '40; Floyd A. Lyon '42; Denman K. McNear '48; Rhonda E. Peck '82.

Their contributions to MIT are deeply appreciated, and we look forward to their continuing participation in the life of the Institute through committee service, Campaign activities, and alumni affairs.

Elections

Effective July 1, 1988, the following nine members were elected to the Corporation for the terms indicated:

For Five Years Beginning July 1, 1988: Robert A. Charpie; Herbert H. Dow '52; Margaret Coleman Haas '50; David H. Koch '62; Angus N. MacDonald '46; H. DuBose Montgomery '71; Robert A. Muh '59; Frank S. Wyle '41. (Messrs. Charpie, Dow, MacDonald, and Wyle have all served previous terms.)

For Five Years Beginning October 1, 1988: Megan J. Smith '86.

Two members of the Corporation were elected to Life Membership, effective July 1, 1988: Joseph G. Gavin, Jr., '41; Mary Frances Wagley '47.

Alumni Association President

On June 30, Raymond S. Stata '57 completed his term of service as President of the Alumni Association and was succeeded by Emily V. Wade '45. We express our appreciation to both these Corporation members for their willingness to take on such a demanding assignment. Mrs. Wade is the second alumna to serve in this position.

Transfer to Emeritus Status

Under Section 5.2 of the Bylaws, Semon E. Knudsen, having reached the age of 75, transferred to the status of Life Member Emeritus. At the October, 1987, meeting of the Corporation, Dr. Saxon read a tribute to Mr. Knudsen.

Deaths

At the March meeting of the Corporation, Dr. Thorn, on behalf of an ad hoc committee that included Mr. Cabot (Thomas) and former MIT Presidents Stratton, Johnson, and Wiesner, presented memorial resolutions honoring James R. Killian, Jr., Life Member Emeritus. Dr. Killian died on January 29, 1988.

At the May meeting of the Corporation, Mr. Johnson presented memorial resolutions honoring Life Member Emeritus Walter J. Beadle, who died on February 8, 1988.

CORPORATION COMMITTEES

Executive Committee

This committee is chaired by the President and includes the Chairman and Treasurer ex officio and seven elected members, who this year were Messrs. Atwood, Gavin, Mueller, and Vetter and Drs. Austen, David, and 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). In addition to its regular agenda of reports from the senior officers and budget and salary reviews, the Executive Committee spent considerable time in the past year on the issues related to the phasing out of the ABS department. The President, the Provost, and the Chairman of the Faculty discuss this event and its repercussions in their respective annual reports. In March, 1988, Mr. Atwood resigned from the Committee because his expanded responsibilities at General Motors have placed extraordinary and unexpected demands on his time. There was no replacement for him during the spring term. The second year of his two-year term will be filled by Mr. Vetter, who has graciously agreed to extend his service on this committee by one year for this purpose. In September, Dr. Tanenbaum will begin a two-year term of service.

Corporation Development Committee

The activities of this committee during the past year are covered in the report of the Vice President and Treasurer.

Investment Committee

The Investment Committee met four times during the past year. Representatives of the firm of Thorndike, Doran, Paine, & Lewis, which serves as investment manager and advisor on general investments, participated with appropriate members of the MIT administration in these meetings. The committee reviewed the status of the general investments, considered various investment proposals, and provided recommendations for the distribution rate to Pools A and C of the general investments. The general investments are more completely described in the Report of the Treasurer. On July 1, 1987, Mr. Kerr, who had been a member of the committee for the prior five years, succeeded Mr. Mueller as Chairman. Mr. Mueller continues as a member of the committee. Dr. Saxon and Mr. Strehle serve as ex officio members of the committee. Other members this year included Messrs. Reed, Haas, Cary, du Pont, and Mr. Patterson, who on June 30, 1988, completed almost fourteen years as a member of the committee.

Membership Committee

The Chairman of the Corporation chairs the Membership Committee, which this year included Messrs. Gray, Johnson, Kane, Leventhal, and Swanson, and Ms. O'Brien, who is the first woman to serve on this committee. The committee followed the practice of previous years, holding formal meetings in October and December for substantive discussions of membership matters. In the remaining months of the academic year, the members stayed in touch by telephone and mail to exchange suggestions and review nominations. The results of this year's deliberations are recorded earlier in this report.

Dr. Fulbright, Chairperson, and the other members of the Screening Committee, Mr. Koerner, Mses. Peck, Roane, and Tabler worked diligently with Mrs. Dorothy G. Adler of the Alumni Office to provide a slate of candidates for the special election by which a recent graduate is nominated to membership in the Corporation. The Corporation Screening Committee met three times during the 1987-88 academic year: one open meeting with students in November, 1987, a committee teleconference in January, 1988, and an all-day meeting at MIT in February, 1988. The five members of the committee chose a ballot of seven nominees from a group of 85 candidates from the classes of 1986, 1987, and 1988 to elect a representative from recent classes to serve on the Corporation for a five-year term. Ms. Megan Smith was the winner of the special election, as indicated above.

Auditing Committee

The Auditing Committee was chaired again this year by Mr. Muckley and included Mrs. Bok and Messrs. Cabot (Louis), George, and Jamieson as members. There were two meetings, one on October 1, 1987, and one on March 3, 1988. 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, 1987, while the spring meeting was devoted to setting the scope of the audit for the year ending June 30, 1988, and reviewing the report of internal audit operations.

Advisory Committee on Shareholder Responsibility

The Advisory Committee on Shareholder Responsibility (ACSR), under the chairmanship of Mr. Weedon and with the Treasurer serving as an ex officio member, met three times during the past year. Through its reviews of proxy questions, it assisted the Executive Committee on matters concerned with MIT's actions as a socially responsible owner of corporate stocks. Staff work was provided by Walter L. Milne, Assistant to the President and to the Chairman of the Corporation, and Ronald P. Suduiko, Special Assistant to the Chairman.

In addition, Mr. Milne, as secretary of the ACSR, met with the Executive Committee in December to review MIT policy on South Africa-related investments. Following this review, the Executive Committee reaffirmed the Institute's policy governing such MIT investments and reported this decision to the Corporation at its December meeting.

Corporation Joint Advisory Committee on Institute-Wide Affairs

Under the continuing chairmanship of Mrs. Wade, the Corporation Joint Advisory Committee on Institute-Wide Affairs (CJAC) held four meetings during 1987-88. Also serving on this committee were Messrs. Stata (ex officio), Bevington, and Bodman, and Ms. Peck and Roane.

The first meeting discussed possible agenda for the year. Following the meeting, CJAC members attended a dinner with the Corporation Screening Committee and student leaders, and later an open meeting to discuss the functions of MIT trustees and the process by which recent graduates become candidates for membership on the Corporation.

The University Park development and related protest activities were ongoing agenda items. Representatives from the offices of the President, the Chairman, and the Treasurer and also the Department of Urban Studies and Planning reported on key issues.

Throughout the year the committee was updated on the status of last year's proposal to bring South African scholars to MIT on a one-year exchange program. A core group of faculty is attempting to set up joint research projects focused on housing, energy, and trade unions.

Other agenda items included a discussion of the Visiting Committee process, the funding for student activities, and the future of dormitories and fraternities.

Corporation Visiting Committees

Since their establishment in 1875, Visiting Committees have influenced the course of education and research at MIT. Through biennial meetings and reports, committee members provide important appraisal and advice to the Corporation, administration, faculty, and students.

During the academic year 1987-88, approximately 400 members (74 Corporation members, 141 alumni nominees, and 185 presidential nominees) occupied 450 slots on the twenty-six Corporation Visiting Committees. Fourteen committees held meetings:

<u>Fall 1987</u>	<u>Visiting Committee</u>	<u>Chairman</u>
October 7-8	Materials Science and Engineering	Robert L. Mitchell
October 28-29	Nuclear Engineering	Edward O. Vetter
November 4-5	Architecture and Planning	Norman B. Leventhal
November 9-10	Mechanical Engineering	E. R. Kane
November 17-18	Civil Engineering	Harold J. Muckley
December 2-3	Chemistry	Paul M. Cook
<u>Spring 1988</u>	<u>Visiting Committee</u>	<u>Chairman</u>
February 23-24	Linguistics and Philosophy	Edward E. David, Jr.
March 2-3	Earth, Atmospheric, and Planetary Sciences	Breene M. Kerr
March 8-9	Libraries	Rita A. O'Brien
March 29-30	Aeronautics and Astronautics	Joseph G. Gavin, Jr.
April 6-7	MIT Sloan School of Management	Colby H. Chandler
April 13-14	Athletics	E. Milton Bevington
May 3-4	Biology	Robert A. Swanson
May 9-10	Whitaker College	W. Gerald Austen

All pending oral and written reports for committees which met during 1986-87 were completed, as well as ten oral and four written reports for 1987-88 meetings. Membership for twenty-five of the twenty-six Visiting Committees was replenished; with the closing of its department, the Applied Biological Sciences Visiting Committee completed its service this year.

MEETINGS OF THE CORPORATION

Orientation Program

On October 1, 1987, the day preceding the Annual Meeting, an orientation program was held for new members of the Corporation and their spouses. The program included luncheon at the President's House with senior officers and staff members followed by an afternoon program of presentations by officers of the Corporation on the structure of the trustee body and an overview of the Institute by the President. After the formal presentations there was a two-hour conducted tour of the campus followed by a dinner at which the new members and their spouses were joined by the members of the Executive and Membership Committees and their spouses.

Annual Meeting

Prior to the start of the Annual Meeting on October 2, 1987, the Corporation posed for a group picture in the garden of the President's House with very satisfactory results. It has been the custom to take such a picture every 3-4 years. Both the President and the Treasurer presented their annual reports at this meeting, and the Vice President and Treasurer also presented a report on the progress of the Campaign for the future. Following the business session, members of the Corporation were joined at luncheon at the Faculty Club by members of the Faculty Council. There was no formal program in order to provide maximum opportunity for conversation between the two groups.

December Meeting

When the Corporation met at the Plaza Hotel in New York City for its quarterly meeting on December 4, 1987, it was the first time in more than a decade that this body had met outside Massachusetts. A highlight of this meeting was the adopting of formal resolutions honoring Professors Robert M. Solow and Susumu Tonegawa, both of whom received Nobel Prizes that month. The meeting was well attended and included several former members of the Corporation present by invitation. The meeting was preceded by a gala dinner the evening before, the first major event held away from the MIT campus to mark the formal beginning of the Campaign for the future. Professor Solow was the featured speaker. This event will be covered in the Annual Report of the Vice President and Treasurer.

March Meeting

At the meeting on March 4, 1988, there was extensive discussion about the decision of the Administration to phase out the Department of Applied Biological Sciences. Many Corporation members took part in this discussion, and the President welcomed the comments of the members, some of which were critical of some aspects of the decision and of the way it was carried out. The substance of that discussion and the Corporation members' views were referred to the Executive Committee. The views expressed by the Corporation on this occasion have helped to bring about clarification and some important changes in the procedures associated with the formal closing of major academic units.

Following the business session, members of the Corporation and accompanying spouses met for luncheon at the Chairman's residence, where they were joined by members of the Academic Council, their spouses, and special guests. Dr. David Baltimore, Nobel Laureate and Director of the Whitehead Institute, addressed the luncheon group on the subject of AIDS in Perspective.

Commencement Meeting

The Corporation held a brief breakfast meeting prior to the Commencement exercises, which this year fell on Friday, May 27, 1988. The annual elections were held at this meeting, the results of which have been noted earlier in this report.

Following the meeting, 29 members of the Corporation marched in the academic procession to Killian Court. Dr. Saxon presided at the exercises, and Dr. Gray delivered the charge to the graduates. As President of the Alumni Association, Mr. Stata was the Chief Marshal, and Mr. McNear served as Marshal of the Corporation. Mr. Leventhal marched with the Class of 1938. The Commencement address was delivered by A. Bartlett Giamatti, President of the National League of Professional Baseball Clubs and former President of Yale University.

It was noted with sadness that this was the first Commencement in many years which was not attended by James R. Killian, Jr.

SPECIAL EVENTS

Dedication of The Green Center for Physics

At its quarterly meeting on October 2, 1987, the Corporation adopted a formal resolution expressing its pleasure at the action of the Executive Committee in naming The Green Center for Physics in honor of Cecil and Ida Green. On October 22, 1987, there was a memorable ceremony at which Mr. Green was present to unveil a plaque commemorating the naming of this important new center at MIT. Eventually The Green Center will be located in renovated space that now houses the Department of Biology, for which a new building is to be constructed. For now this handsome plaque is located over the portal at the entrance to Building 6 near the present headquarters of the Physics Department. This celebration was the last MIT event that Dr. Killian attended.

Dedication of Elizabeth Parks Killian Hall

At its meeting on March 6, 1987, the Corporation was informed of a vote of the Executive Committee a month earlier approving the naming of space in the Charles Hayden Memorial Library for Elizabeth Parks Killian, wife of the former President and Chairman of MIT. On December 13, 1987, in that space, now transformed into a musical salon, there was a formal dedication ceremony at which Dr. Saxon presided. It was followed by a concert of the MIT Chamber Players under the direction of Professor Marcus Thompson. There was an overflow audience, which included Corporation members from the Boston area, and the entire event was videotaped for Dr. Killian, who was unable to attend for reasons of health. President and Mrs. Gray invited the audience and the performers to the President's House for tea following the concert.

Naming of the Johnson Athletics Center

At its meeting on October 2, 1987, the Corporation accepted by acclamation the recommendation of the Executive Committee that the Athletics Center be named in honor of Howard W. Johnson, Honorary Chairman of the Corporation. At its meeting on March 4, 1988, the Corporation adopted formal resolutions to be associated with the celebration which took place in the following month on April 22-23, 1988. On Friday, April 22, Dr. Saxon, presiding at the naming ceremony held in the Athletics Center, announced the establishment of the Howard W. Johnson Professorship of Management and the creation of a Sloan School lectureship also honoring Mr. Johnson.

The next day, Saturday, April 23, an estimated 1300 members of the MIT community took part in a series of friendly and spirited athletic and mental competitions as part of The Johnson Games. Elaborate plans and formation of teams, each made up of students, faculty, and staff, preceded the Games for a month. Following the Games, President and Mrs. Gray hosted an Institute ball, on this occasion appropriately named The Athlon Ball, which was attended by more than 800. As the President reported to the Corporation at the Commencement meeting, there was a wonderful sense of community experienced on that special MIT day, and tremendous enjoyment, providing a fitting and warm-hearted tribute to Howard Johnson.

Memorial Service for James R. Killian, Jr.

On May 5, 1988, a memorial service was held in Kresge Auditorium honoring MIT's distinguished former President and Chairman, James R. Killian, Jr. There was a large audience with many Corporation members in attendance. Speakers included the President, the Chairman, and the Honorary Chairman as well as President Emeritus Jerome B. Wiesner, Institute Professor Emeritus Victor F. Weisskopf, distinguished journalist Bill Moyers, and the minister from the First and Second Unitarian Church of Boston, Dr. Rhys Williams. Music was provided by the MIT Symphony Orchestra and the MIT Chamber Chorus, and the service was concluded with a stirring rendition of The Battle Hymn of the Republic, specifically requested by Dr. Killian.

STAFF CHANGES

On January 1, 1988, Elizabeth J. Whittaker was named Associate Secretary of the Corporation. This is a new title, and the action was taken by the Secretary, with the approval of the Executive Committee, in order to recognize the position's growing functions over the past two years, and the dedicated manner in which Miss Whittaker carries out her senior staff responsibilities.

Lois A. Graham transferred from Resource Development to the Secretary's Office on November 2, 1987, to assume the duties of Assistant to the Secretary of the Corporation. In addition to her primary responsibility of managing Visiting Committees, Ms. Graham also provides valuable assistance to the Vice President and Secretary in a variety of other staff functions and projects, including the liaison with MIT's legal counsel.

CONSTANTINE B. SIMONIDES

Council for the Arts

In this, its seventeenth year, the Council exercised the patience requested of it by Provost John Deutch in response to the Report of the Committee to Review the Arts at MIT, while the Council staff carried out its usual array of activities.

Annual Meeting

The Sixteenth Annual Meeting of the Council took place on March 18. Chairman Jerome B. Wiesner introduced President Paul Gray to welcome Council members and then asked Provost John Deutch to present the Institute administration's response to the Report of the Committee to Review the Arts at MIT. (His presentation was substantially identical to the one he made to the Council's Executive Committee on December 17. The Minutes of that meeting are available separately.)

Stephen Immerman, Director of Operations for the West Campus, described the ongoing renovation of the Stratton Student Center and pointed out the many internal space reconfigurations that will facilitate informal performing arts presentations.

After a box lunch in the atrium of the Wiesner Building and visits to the List Visual Arts Center galleries, the Council heard a discussion on creativity at MIT chaired by Associate Provost Samuel J. Keyser.

At mid-afternoon Council members adjourned to Elizabeth Parks Killian Hall, MIT's newly renovated music performance facility. There, Nancy Cavanagh, Administrative Officer of the Music and Theater Arts Section, described the transformation of the hall from the former Hayden Gallery into a concert space. Council members were entertained by a selection of student performances in puppetry, video, drama, and music, which had received funding from the Grants Program.

The 1988 Kepes Prize was presented, by Angus MacDonald '46, to C. Fayette Taylor, Professor Emeritus of Mechanical Engineering, for his work in metal sculpture. Ida Rubin presented the 1988 McDermott Award to Council member Yulla Lipchitz for her work in photography. Marc Scheps, Director of the Tel Aviv Museum of Art, spoke in Yulla's honor at the Council's dinner, held at the Royal Sonesta Hotel, compliments of former Council member Roger Sonnabend '46.

Grants Program

This year, the Grants Committee, chaired by Bradford M. Endicott '49, received and evaluated 63 proposals from students, student groups, faculty, and staff, requesting a total of \$104,689. Of these, 49 projects (78 percent of those submitted) were awarded \$64,371 (61 percent of the amount requested). In addition, Council staff made five Officers' Grants for \$985. A detailed report from the Grants Committee is available.

Substantial grants were awarded to the Student Art Association to purchase photographic equipment to bolster its popular basic photography courses, and to the MIT Music and Theater Arts Section in support of the year-long concert series "Composers in Recital," highlighting contemporary American composer/performers.

Publications

Four issues of the Council's calendar/newsletter, The Arts at MIT, were produced and distributed to a mailing list of 8,500 alumni, friends, faculty, staff, student groups, and other individuals.

The Arts Hotline, a weekly telephone announcement of all arts events taking place at MIT, was maintained for its fourth year.

Endowed Prizes and Awards

The Laya and Jerome B. Wiesner Student Art Awards were presented to Kirsten Hoyte '90 (Course XVII) for her contributions to the Dramashop, and to Julio Friedmann '88 (Course XXI) for his work in music and drama. The Louis Sudler Prize in the Arts was awarded to graduating senior Ellen Lin for her contributions to the MIT Symphony Orchestra and other music ensembles.

William M. Siebert, Ford Professor of Engineering, served as the Chairman of the Student Art Awards Selection Committee.

Independent Activities Period

During IAP, the Council again sponsored a very successful series called "ART: A User's Guide," which consisted of four arts field trips. Forty-five students attended a concert by the Boston Chamber Music Society, a tour of the exhibitions at the List Visual Arts Center, a production of August Wilson's "The Piano Lesson" by the Huntington Theater Company, and a performance of multicultural dance by choreographers Kei Takei and Uttara Coorlawala. Before each event, a faculty or staff member presented an informal lecture to illuminate the program; this year's guest speakers included Lowell Lindgren, Professor of Music, Dana Friis-Hansen, Assistant Curator of the Committee on the Visual Arts, and Robert Scanlan, Lecturer and Director of the Dramashop.

William L. Abramowitz Memorial Concert

The William L. Abramowitz Memorial Concert endowment provides funds for the Council to present a major performance event every 12-24 months. This year, on March 30, a near-capacity crowd filled Kresge Auditorium to hear the internationally acclaimed, Netherlands-based, 10-piece jazz ensemble, The Willem Breuker Kollektief.

In his review of the concert, published in The Tech, Mark Roman said:

[The Kollektief's] music is a manic and eclectic blend of folk music, blues, Tin Pan Alley, Broadway, the finest of collective improvisational jazz and Vaudeville--all rolled into a jazz concert that transcended the usual idea of a recital and moved more towards a piece of musical performance art.

Boston Museum of Fine Arts University Membership Program

For the eighth year, the Council funded MIT's participation in the MFA's University Membership Program which allows all MIT students to attend the Museum at no charge as frequently as they wish. This year's participation was made possible by special contributions from Bradford M. Endicott '49, and Bernard G. Palitz '47.

Institute of Contemporary Art Membership

Beginning this year, through the generosity of Ellen Poss, Boston psychiatrist and member of the board of the Institute of Contemporary Art, MIT students are now also able to attend the ICA at no charge and as frequently as they wish.

Programmatic and Technical Assistance

Council staff have continued to provide advice, ideas, research, and administrative support regarding the development of arts projects or organizations to MIT students, faculty, and staff. In particular, Mark Palmgren continued to assist a task group of the MIT Working Group on Support Staff Issues to develop a Support Staff Art Exhibition.

Development Activities

Most of the Council's funds for both its operating expenses and Grants Program continued to come from Council members and other donors. This year, 54 members made contributions averaging \$4003 each, and 27 other donors contributed an average of \$763 each.

Provost John Deutch announced to the Council's Executive Committee meeting on December 17 that the administration had accepted the recommendation of the faculty Review Committee that the Institute cover Council staff salaries and operating expenses, thus releasing all funds raised from and through the Council to the support of programs. Later in the year, Provost Deutch authorized the contribution of \$100,000 from general funds to the Council for FY89.

Gifts of Works of Art

Council members have regularly contributed works of art to the MIT Permanent Collection and to the Student Loan Collections. This year, Vera G. List contributed works by Jennifer Bartlett, Peter Bonnels, Mary Frank, Ralph Humphrey, and Joel Shapiro to the Permanent Collection. To the List Student Loan Program, she gave works by Berenice Abbott, William Bailey, Susan Crile, Don Eddy, Eric Fischl, Mary Frank, Sergio Gonzalez-Tornero, Judith Murray, and William Zimmerman. Mrs. List also established, by means of a generous cash gift, the Albert and Vera List Visual Arts Center Endowment for the Committee on the Visual Arts.

Ronald A. Kurtz '54 made a third gift of black and white photographs by Berenice Abbott: 176 to the Ronald A. Kurtz Student Loan Collection and 13 to the Department of Materials Science.

Membership

At the end of the year, Council membership stands at 84. Two Council members died during the year: James Killian (on January 29) and Bartlett Hayes (on February 14). Albert List passed away in September.

Peggy Lamson joined the Council for a three-year term beginning July 1, 1988.

All of the 16 members whose terms expired this year were asked to renew their commitments.

Personnel

Lee Higgins joined the staff in September as Senior Staff Assistant, following the resignation of Susan Downing, who became Company Manager of the MIT Shakespeare Ensemble. Associate Director, Richard A. MacMillan, resigned from the staff on March 31 to become Director of Corporate Support Programs for the Massachusetts Council on the Arts and Humanities.

HELVI McCLELLAND

List Visual Arts Center

In anticipation of the eventual hiring of an Associate Provost for the Arts, (as recommended by the Committee to Review the Arts at MIT), the List Visual Arts Center (LVAC) continued to operate a full complement of programs without a Permanent Director. Katy Kline continued to serve as both Curator and Acting Director; the part-time curatorial assistant and the program consultant hired last year were retained. Staff energies were directed toward implementing an unusually ambitious exhibition schedule as well as toward increasing the public visibility of programs. With a subsidy from the MIT Council for the Arts, a two-minute videotape describing LVAC programs was produced through the Around Town Network and was shown on cable systems throughout the greater Boston area. Weekday gallery hours were changed from 10 - 4 to 12 - 6 in an attempt to capture an after-work audience.

The Committee on the Visual Arts, a presidentially appointed group composed of faculty, administrative staff, and students, an advisory board to the professional staff of the List Center, met four times under new Chairman Peter Wolff. Its deliberations focused on the future of the program, the desirable qualities and background to look for in the Associate Provost, on ways to increase student involvement in programs, on means of expanding the Student Art Loan Program, and other topics.

Outside funding continued to be crucial to the implementation of programs. The National Endowment for the Arts awarded monies for three artists' residencies and for the exhibition Three on Technology. The LVAC once again received one of the largest awards from the Massachusetts Council on the Arts and Humanities, with grants toward the artists' residencies, a workshop series and performance of electronically advanced hybrid instruments; toward commissioning catalogue essays from several West Coast writers; and toward the research costs of organizing an upcoming exhibition of contemporary Japanese art. Other sources of outside support were PRO-HELVETIA (Swiss Cultural Office); the Polaroid Foundation, Bank of Boston, Goethe Institute, W.R. Grace & Co., and MIT Council for the Arts. Outside funding for the fiscal year totalled more than \$120,000.

EXHIBITION PROGRAM

The eleven exhibitions in the three galleries of the List Visual Arts Center presented adventurous contemporary art in a variety of media. Attendance continued on an upward curve, and exhibitions were favorably reviewed in local, regional and national media, including The Boston Globe, The Boston Herald, WBUR's "Performance Today," Art New England, The New York Times and Artforum. The Boston Phoenix art critic wrote, for example, "The List Visual Arts Center has mounted the most balanced contemporary art exhibitions in the area. The current line-up is not only the best contemporary show of the spring, it is indicative of the broad-minded and intelligent approach regularly taken by curatorial staffers Katy Kline and Dana Friis-Hansen".

1987-88 Exhibition Schedule

Student Art Loan Exhibition and Lottery, Hayden and Reference Galleries, September 1 - September 18. The popular annual exhibition and lottery of nearly 300 prints and limited edition artist-designed posters available free to students for their living quarters.

Jenny Holzer: Signs, Hayden Gallery, October 9 - November 29. Organized by the Des Moines Art Center, a survey of the artist's trenchant writings which appeared on electronic message boards, incised granite benches, metal plaques scattered around the Institute, and billboards--both print and electronic--throughout the metropolitan area.

Terry Winters: Schema, Reference Gallery, September 26 - November 29. Seventy-five drawings exploring this well-known contemporary artist's favorite motifs from the realms of botany, biology and geology. Shown in conjunction with the exhibition of his paintings at the Museum of Fine Arts, and with the installation of his painting VESSEL, on long-term loan to MIT, in the Whitaker Building atrium.

Peter Fischli & David Weiss, Bakalar Gallery, October 9 - November 15. Forty photographs and a 30-minute film by this Zurich-based artist duo who play with and document precariously balanced constructions and pseudo-scientific experiments and transformations. 28-page illustrated catalogue published. Exhibition traveled to the Renaissance Society, Chicago; P.S. 1, New York; Museum of Contemporary Art, Los Angeles; University Art Museum, Berkeley, and will conclude its tour at the Dallas Museum of Art.

L.A. Hot and Cool, Hayden and Reference Galleries, December 19, 1987 - February 7, 1988. Painting, sculpture, photography and installation work by 23 emerging Los Angeles artists who represent the two poles of that city's aesthetic climate: the hot, colorful, expressive, narrative mode and the cooler, conceptual, analytical approach. Adjunct exhibition L.A. Hot and Cool: Pioneers, precedents from the 1960s and 70s, organized for the Bank of Boston Art Gallery, November 23, 1987 - January 15, 1988. 72-page illustrated catalogue published.

Ellsworth Kelly: Small Sculpture, Bakalar Gallery, December 19, 1987 - March 27, 1988. A selection of 10 rarely seen works in wood and various metals exemplifying this 20th century master's cool abstract geometry which is always rooted in the lines and forms of the visible world. To coincide with a traveling exhibition of his works on paper at the Museum of Fine Arts. 34-page illustrated catalogue published.

Siah Armajani: Communal Spaces, Hayden Gallery, February 27 - April 17. A major new work, Sacco and Vanzetti Reading Room #2, models for other public projects and a prototype Information Kiosk proposed for MIT's Lobby 7, demonstrating this Minnesota-based artist's spatial solutions which derive from the unique social, historical and functional conditions of the various locations.

Ralph Paquin and Ann Stoddard: ...r-e-m-o-t-e..., Reference Gallery, February 27 - April 10. A month-long residency by this collaborative duo from Dartmouth, Massachusetts who constructed an elaborate, multi-leveled multi-media, motorized, surreal landscape which then served on three successive weekends as the set for a 20-minute performance of an allegorical spectacle alluding to our precarious position between past and future, nature and technology, knowledge and the unknown.

Three on Technology: New Photographs by Robert Cumming, Lee Friedlander and Jan Groover, Hayden Gallery, May 7 - June 26. New work by these leading contemporary photographers, commissioned by the LVAC with funding from the Massachusetts Council on the Arts and Humanities, to document the look and effects on contemporary culture of the current revolution in information technology. 72-page illustrated catalogue published. Exhibition scheduled to tour nationally during 1988-1990.

Kristin Jones and Andrew Ginzel: Charybdis, Reference Gallery, May 7 - June 26. The second artist-in-residence team constructed a room-sized diorama evoking the mythological Sicilian whirlpool and employing ice vapor, flames, water and light to instill a sense of wonder in the mysterious forces and beauty of nature.

Tishan Hsu: Paintings, Bakalar Gallery, May 7 - June 26. Large abstract paintings by Boston-born New York artist (MIT BSAD, M.ARCH) who combines industrial forms and materials with a surreal, electronic media-based imagery to investigate connections between the body, the landscape and technology. 8-page illustrated catalogue published.

Hyperinstruments, Experimental Media Facility (The Cube), June 10-11. Held in conjunction with the Media Lab, this residency with electronic music composers Robert Dick, Gordon Gottlieb, George Lewis, and Richard Teitelbaum, culminated in a series of workshops on the future of musical virtuosity in an environment of "smart machines," and a concert featuring new works written by these composers and MIT faculty and students.

EDUCATIONAL PROGRAMS

A diverse menu of educational programs and exhibition-related events were offered throughout the past season, open free 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.

Talks, Tours, and Lectures

Gallery talks at the List Visual Arts Center and tours of the MIT Collection were arranged for a number of local and visiting groups, including museum member tours, school and community groups, and alumni organizations. From MIT, a freshman seminar, alumni, and an IAP group participated in discussion sessions in the galleries.

Most exhibitions were accompanied by lectures and special events. Jenny Holzer lectured about her art, placing it within a context of other socially-concerned art, and met with members of the Women's Caucus for Art. As a complement to "Terry Winters: Schema," the LVAC hosted a reading by noted New York poet and art critic David Shapiro, who shares Winters' sensibilities towards natural phenomena. Within his exhibition, Siah Armajani publicly presented his design ideas for MIT's Lobby 7; models and a short text condensing his analysis were subsequently placed on display in Lobby 7. Ann Stoddard and Ralph Paquin presented a slide lecture about their past collaborations and discussed plans for their work at MIT. A symposium to examine the issues raised by the exhibition "Three on Technology," was organized in conjunction with the MIT Program in Science, Technology, and Society, featuring scholars Molly Nesbit, Barnard College; John Tagg, SUNY Binghamton; and Alan Trachtenberg, Yale. Finally, Kristin Jones and Andrew Ginzler explored the issues central to their art and surveyed their past work in a slide lecture.

Artists in Residence

The LVAC Artist-In-Residence program--essentially research and development projects--continued to offer invited artists an opportunity to draw upon the Insititute's intellectual, technical, and physical resources in the realization of challenging 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.

Outreach to Students

A special initiative was begun to increase student and MIT community attendance and participation in List Center programs. With emphasis on the Student Art Loan lottery, and on residency projects (which benefit from and often rely upon student participation), strategies were followed to increase campus awareness through Tech Talk, The Tech, LSC slides, and a Lobby 7 drop poster. During R/O Week flyers were distributed and a small exhibition and table was set up at the Student Activities Midway. Visiting artists and LVAC curators were regularly interviewed on WMBR's program "Art Bridge".

ACQUISITIONS

The following works were acquired through either gift or purchase during the 1987-1988 academic year:

Permanent Collection

Jennifer Bartlett, FROM RHAPSODY, (Suite of 3 Prints), 1987, etching (aquatint, hardground, softground, spit-bite, grid photographically reproduced) on BFK paper, ed. 100. Gift of the Albert and Vera List Family Collection.

Peter Bommels, "DAS UBERRASCHEENDE ENDE," 1984, pastel on paper. Gift of the Albert and Vera List Family Collection.

Mark Frank, POPPIES, 1978, monoprint. Gift of the Albert and Vera List Family Collection.

Ralph Humphrey, Untitled, 1977, mixed media on paper. Gift of the Albert and Vera List Family Collection.

Joel Shapiro, Untitled, 1987, woodcut, AP 9/9. Gift of the Albert and Vera List Family Collection.

List Student Art Loan Collection

Berenice Abbott, From the New York Series, 1930's, black and white photograph, ed. 37/40. Gift of the Albert and Vera List Collection.

Berenice Abbott, From the New York Series, 1930's, black and white photograph, ed. 37/40. Gift of the Albert and Vera List Collection.

William Bailey, Untitled (Still Life), 1982, etching, ed. 17/50. Gift of the Albert and Vera List Collection.

Susan Crile, Untitled, n.d., silkscreen, ed. 36/72. Gift of the Albert and Vera List Collection.

Don Eddy, Untitled, n.d., lithograph, ed. 196/250. Gift of the Albert and Vera List Collection.

Eric Fischl, Untitled, 1987, etching and aquatint on rag paper, ed. 60/100. Gift of the Albert and Vera List Collection.

Mary Frank, ROSH HOSHANA 5741, c. 1981, etching, AP. Gift of the Albert and Vera List Collection.

Sergio Gonzalez-Tornero, ON EDGE, 1981, intaglio, ed. I/XVIII. Gift of the Albert and Vera List Collection.

Judith Murray, Untitled, n.d., serigraph, ed. 27/72. Gift of the Albert and Vera List Collection.

William Zimmerman, CENTER OF GRAVITY, 1985, etching, ed. 22/50. Gift of the Albert and Vera List Collection.

Ronald A. Kurtz Student Art Loan Collection

Berenice Abbott, 176 black and white photographs, various subjects, various dates. Gift of Ronald A. Kurtz, '54.

EXTENDED LOANS TO THE COLLECTION

(See previous reports.)

LOANS FROM THE PERMANENT COLLECTION TO OTHER INSTITUTIONS

Elizabeth Murray, LAST NIGHT, 1982, to the Museum of Contemporary Art, Los Angeles for the exhibition Elizabeth Murray: Paintings and Drawings, July - September 1987 and subsequent tour to the Des Moines Art Center, IA; Walker Art Center, Minneapolis, MN; and The Whitney Museum of American Art, New York, NY. This exhibition was co-organized by the MIT Committee on the Visual Arts and the Dallas Museum of Art; it premiered in Dallas in February 1987 and was hosted by the MIT List Visual Arts Center along with the Museum of Fine Arts, Boston, before continuing on to Los Angeles and the subsequent three sites.

Beverly Pepper, TRINITY, (formerly DUNES I), 1971, to The Brooklyn Museum, NY, summer of 1987, for the traveling exhibition Beverly Pepper: Sculpture in Place which had previously been hosted by the Albright-Knox Art Gallery, Buffalo, NY; the San Francisco Museum of Modern Art, CA; and the Columbus Museum of Art, OH.

Vassilikis Takis, ELECTROMAGNETIC I, 1962 and Wen-Ying Tsai, CYBERNETIC SCULPTURE #301, 1970, to the MIT Center for Advanced Visual Studies, April, 1988, for their 20th year Anniversary Celebration. Both Takis and Tsai are former fellows of the CAVS.

CONSERVATION TO THE PERMANENT COLLECTION

Alexander Calder's THE BIG SAIL (La Grande Voile) and Louise Nevelson's TRANSPARENT HORIZON both were painted.

Terry Winters' painting VESSEL, 1985, on long-term loan to the Permanent Collection, was framed in preparation for siting in the Whitaker College of Health Sciences, Technology and Management.

65 photographs and works on paper were framed or re-framed by Old Cambridge Co., Cambridge.

LVAC Staff
PETER A. WOLFF

VICE PRESIDENT FOR FINANCIAL OPERATIONS

The past five years of small surpluses in operations (Fiscal 1984-1988) are directly related to the strong growth in research volume on and off campus during this period, although the research base on campus experienced less growth in Fiscal 1987 and 1988. Our best estimates of research growth in the next few years is that there will be no growth and the strong possibility of even a decline in total research volume. In setting the indirect cost rate for Fiscal Year 1989, we projected zero growth in the research base on campus for Fiscal Years 1989-1991, and indications are that growth at Lincoln Laboratory will also level off during these years. The Presidential election this Fall adds uncertainty to the future direction of research efforts for the nation and MIT.

When research volume declines, or fails to match the growth in the instructional program, the Institute is affected in several major ways; one, faculty and research staff have reduced direct dollars for their research efforts, two, more of the costs of Institute operations are borne by Institute general funds as research sponsors reimburse less of these costs (without other sources of revenue, the deficit increases), and three, as the research base declines, the indirect cost rate increases to cover the costs allocated to research (which affects the principal investigators ability to attract research funding).

Projections for the next few years show an elimination of the surplus position and growing deficits. The increasing deficits are primarily the result of declining revenues as expenses have been carefully controlled over the past few years, including a reduction in support services of 15% over the three-year period of Fiscal 1983-1985. Following an increase of approximately 3% in Fiscal 1986, we have held the overall support services budget at almost the Fiscal 1986 level since, except for salary increases and items such as utility costs, legal and other service charges, and the necessary expenses associated with the *Campaign for the future*.

It is important to note that the growing 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 many gifts, which are increasing significantly as a result of the success of the *Campaign for the future*, flow into the restricted portion of the endowment.

We do not yet have a totally clear view on the best way to proceed at this time as there are many variables to consider, and a number of factors which are unpredictable because of uncertainty in funding, particularly at the national level, on such issues as research funding and continuing support for student financial aid.

We do not want to project a financial situation that indicates very severe shortfalls between revenues and expenses (requiring the necessary significant reductions in cost--primarily in staff since such a large percentage of our costs are people related) if, in fact, the environment changes in such a way as to restore growth in research efforts and the *Campaign for the future* achieves its goal of limiting the demand for unrestricted funds.

Conversely, we do not want to be complacent about these shortfalls, which could become even more significant in the future, and permit the Institute to become less financially sound than it is at present.

The correct measures to assure growth and continued financial strength for the future of MIT, in this uncertain era, requires a good deal of careful thought prior to implementation. During the coming year, a systematic analysis of the various options open to us to restore the balance between operating revenues and expenses will be undertaken in the expectation of developing a comprehensive plan for the Fiscal 1990 budget cycle.

Many members of the Financial Operations area will be involved in this effort, 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 development of a number of management training programs which will commence this year. Under the leadership of Dr. John S. Wilson Jr., a staff member in the area, many individuals have worked exceptionally hard to assure that these programs were satisfactorily designed and implemented. The programs include a Financial Management Program, in which 30 staff members will spend 14 sessions covering topics relevant both to the overall mission of MIT and specific to its financial management. Two such programs will be conducted each year until all interested staff members have attended. A number of other programs, including 6 all-day seminars on management topics, a summer-internship program for college students, and a number of career/job related seminars for supervisors and supervisees, will be conducted. We look forward to these programs being effective in improving productivity and morale.

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 attention and careful effort 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, 1988, the total number of women administrative staff is 75 (39%), while underrepresented minorities are 16 (8%) of the administrative staff of 195, (In 1987, these figures were 70 (38%) and 16 (9%) of 185, respectively.)

Including support and service staff members, the percentage of underrepresented minorities is 46 (12%) of a total staff of 393, (In 1987, these figures were 46 (12%) of 386.)

A statistical analysis of affirmative action results follows for each major area of Financial Operations:

Comptroller

Comptroller's Accounting Office, Lincoln Laboratory Fiscal Office, Audit Division and Property Office

The number of women administrative staff members is 32 (34%) out of a total administrative staff of 94.

The number of underrepresented minorities is 19 (10%) out of a total staff of 195.

Office of the Director of Finance

The number of women administrative staff members is 6 (46%) out of a total administrative staff of 13.

The number of underrepresented minorities is 2 (14%) out of a total staff of 14.

Office of Purchasing and Stores

The number of women administrative staff members is 4 (18%) out of a total administrative staff of 22.

The number of underrepresented minorities is 10 (13%) out of a total staff of 77.

Office of Registration and Student Financial Services

The number of women administrative staff members is 23 (59%) out of a total administrative staff of 39.

The number of underrepresented minorities is 13 (19%) out of a total staff of 67.

Office of Sponsored Programs

The number of women administrative staff members is 9 (45%) out of a total administrative staff of 20.

The number of underrepresented minorities is 2 (6%) out of a total staff of 45.

James J. Culliton

Office of the Comptroller

THE COMPTROLLER'S ACCOUNTING OFFICE - CAMBRIDGE

Payroll

The Staff Payroll Disbursement function was successfully implemented in July 1987, leaving only the Staff Distribution part of the Payroll Project to be completed. Work was then suspended on the project in favor of complying with new regulations required by the Tax Reform Act of 1986; new health and life insurance benefit plans offered by the Institute, and new tax reporting requirements issued by the Internal Revenue Service. In the spring, work was resumed on the Payroll Project toward a fall implementation of the distribution/accounting function.

Benefits Accounting

Accounting and administrative procedures were implemented for the new benefits offered in January 1988 dental insurance, Blue Cross/Blue Shield Option 2, and a revised group term life insurance program. We adjusted manual operations and data entry procedures as required by the new open enrollment forms.

The Retirement Plan for Employees computer system was converted for operating under CMS and a Past Service Benefit uplift was applied to active accounts effective July 1, 1987.

Planning, design, and implementation was begun for an interactive Pension/Payroll System to replace the MSA Payroll System. The new system will tie in and share the data base of the Pension Accounting System.

THE LINCOLN LABORATORY FISCAL OFFICE

On April 1, 1988, the Lincoln Fiscal Office went "live" with an automated purchasing system for Lincoln Laboratory. In addition to Purchasing, this system also interfaces with Receiving, Shipping, various stockrooms, Property, Accounts Payable, and the requisitioners within the laboratory. At the present time, only two divisions are on-line for preparing requisitions. The remaining divisions will be phased in during the next few months.

The Lincoln Fiscal Office will continue the development of automated procedures and control systems as well as improving the operational programs of all systems.

THE PROPERTY OFFICE

The Property Office is responsible for the accounting and asset management of more than 130,000 items of equipment which are both MIT-owned as well as sponsor-owned. During the year, over 9,200 newly acquired items of movable equipment were identified and tagged. Two hundred fourteen final inventories and 505 financial reports were submitted to various government agencies. One hundred ninety thousand dollars (original acquisition cost) of excess government equipment was acquired. One thousand forty one items of equipment with an acquisition value of \$602,930 were transferred between MIT departments as part of a reutilization program; and unneeded equipment sold for \$111,760, providing funds for replacement equipment. The Property Office maintains an inventory of equipment available for reutilization or sale which is displayed at the MIT Equipment Exchange.

Design of a new Property System was begun in conjunction with Administrative Systems Development. The new system will run on a recently acquired MICROVAX Model 3500 which will be under department control.

The Society for Property Administrators, which is administered by the Property Office, conducted a three-day Property Management Conference in Hilton Head, South Carolina, in November 1987. More than 150 attendees from the United States and Canada were present at the conference.

THE AUDIT DIVISION

Throughout the year, the Audit Division continued to provide its traditional service of verification that adequate internal controls are being maintained, that management policies and procedures are being adhered to as intended, and that assets are properly safeguarded. These examinations enable the Audit Division to identify errors and monitor their resolution, to offer recommendations for improvements, and to verify implementation of proposed recommendations or alternative procedures.

Under a new Audit Director, a campus-wide review was launched this past year to evaluate compliance with MIT's requirements for monitoring the monthly Comptroller's Accounting Office (CAO) statements detailing revenues and expenditures by account. The objective of this effort is to increase awareness that the integrity of MIT's accounting data relies upon timely monitoring of monthly CAO statements, and to emphasize the obligation that MIT has to third parties who have entrusted the Institute with significant sums of money. Our efforts will concentrate on adherence to the "Guidelines for Reviewing Monthly Accounting Statements" and will continue throughout Fiscal Year 1989.

Data processing audit coverage increased over 70 percent during the past year allowing for involvement in the many new application systems under development. A full review of the Institute's primary computer facility was also completed as a result of the increased emphasis on the data processing environment.

Other major reviews included the audit of federally funded Student Financial Assistance (SFA) programs for Fiscal Year 1987. This was the last SFA review to be performed by the Audit Division as new Federal Government regulations require external audits of SFA programs.

Personnel Changes

The following staff changes occurred within the Comptroller's Office during the past year:

<u>New Appointments</u>	<u>Promotional Appointments</u>
James F. Bixby Senior Systems Programmer	Robert P. Casey Staff Accountant
Robert N. Clark, Jr. Assistant Auditor	Maynard E. Charles Staff Accountant
William J. Fitzgerald Data Processing Manager- Payrolls and Benefits	Donald R. Comeau Property Administrator
Eugenia L. Gordon Senior Analyst/Programmer	Richard R. Janus, Jr. Staff Accountant
Steven T. Holzinger Consultant I	Martin J. Kelly Staff Accountant
Elizabeth A. Lynds Analyst/Programmer I	Jolanda Scott Staff Accountant
Thomas Maggiacomo Data Processing Manager	Gail B. Tetrault Staff Accountant
James J. McCarthy Senior Analyst/Programmer	Joanne D. Turner Staff Accountant
David J. Tenen Analyst/Programmer II	<u>Retirements</u>
Wayne T. Turner Senior Staff Accountant	John P. Leonard Associate Comptroller 32 years' service
Cynthia C. Westhoff Analyst/Programmer II	
<u>Promotions</u>	
Paul J. Arsenault Senior Accounting Officer	
William P. Cataldo Senior Staff Accountant	
Frederick I. Crowley Assistant to the Comptroller	

John J. Ford
Data Processing Manager

Stephen J. Gorman
Senior Accounting Officer

Demetri A. Karageorge
Accounting Officer

Kathleen M. Lalor
Senior Accounting Officer

Ann M. Langton
Accounting Officer

John S. Lavalley
Assistant to the Comptroller

Anne Mahoney
Senior Staff Accountant

Robert F. Matson
Senior Systems Analyst

Charles A. Shaw
Audit Director

Sheriefa Siers
Senior Analyst/Programmer

Frank J. Silva, Jr.
Senior Staff Accountant

Edith A. Thompson
Assistant Accounting Officer

Lisa J. Walker
Analyst/Programmer II

Cynthia C. Westhoff
Analyst/Programmer III

PHILIP J. KEOHAN

Office of the Director of Finance

Fiscal 1988 Results of Operations

Total operating expenses for the year reached \$945 million - up 7.1 percent from the previous year. Total operating revenues and funds used were \$940.7 million - an increase of 7.0 percent over 1986-1987. In comparison inflation, as measured by the consumer price index for all urban workers, grew by 4.1 percent.

To fund the difference between operating expenses and revenues the Institute used \$4.3 million of the \$4.5 million of unrestricted gifts, grants and bequests it received. The unrestricted gift level of \$4.5 million excludes those gifts restricted by donor, and a large bequest of \$10.5 million from the estate of William H. Ames, class of 1880, which was received as an unrestricted fund, but designated by the Institute as a fund functioning as endowment. This designation by the Institute was done to assure that this large bequest properly recognizes the generous contribution of the Ames estate to MIT.

The surplus from operations after the application of unrestricted gifts, grants, and bequests was \$200,000. This year is the fifth consecutive year that the Institute did not have to utilize the full amount of unrestricted gifts to fund operations.

Financial Planning

There are several cautionary notes for the year that portend difficulty in balancing future budgets. 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 1988 the MTDC base grew by 2.8 percent and instruction and unsponsored research by 9 percent. This differential growth rate reallocates academic administration and support costs from sponsors to unrestricted funds.

Second, is the planned decline in enrollment in both the undergraduate and graduate programs. This combined with the continued need to increase salaries at a rate faster than inflation (particularly for the faculty) puts a strain on a balanced budget.

Third, is the level of unrestricted gifts, grants, and bequests available for the budget. The Campaign for the Future has been very successful with total gifts received in fiscal 1988 increasing by 23 percent to \$80 million compared to the \$65 million received in fiscal 1987. However, most of these gifts are for restricted purposes. The amount of unrestricted gifts available to support operations has not kept pace with inflation over the last decade.

The projected unbalanced budgets for the fiscal 1989-91 period indicate the need to explore three broad approaches to fiscal balance. First is the impact of the Campaign for the Future on the budget and our ability to substitute this source of revenues for the dependence on tuition income. Second, is the exploration of ways to reduce the growth rate of programs and expenses without compromising the academic and research programs. Third is to explore the judicious use of the Institute's reserves during this period of limited or no growth in campus research.

Systems Support for the Budget

During the year a new financial management system for the Budget Office was developed and implemented. The new system is based on a database management software resident on a micro computer that is linked to individual work stations.

The new system was phased in during the spring and was used for the preparation of the fiscal 1989 budget and to close out fiscal 1988. The success and flexibility of the system is apparent to all the budget officers who in the past, had to delve through endless paper trails of financial data.

The following year will see continued enhancement and development of the system.

Personnel and Organization

During the year the Budget Office was reorganized into four sections each headed by an Assistant Director of Finance. The sections are: (1) the annual operating budget (2) research budgets and financial planning, (3) capital budgets, and (4) Systems. These sections are headed respectively by Assistant Directors of Finance Deborah Fairchild, Robert Dankese, Anne Whealan, and Richard Hill.

During the year Deborah Fairchild was promoted to the position of Assistant Director of Finance, Gregory R. Arsenault to the position of Senior Analyst Programmer, and Ugebai Poweigha to the position of Budget Officer I. Sarah Brady joined the group as a Budget Officer II replacing Patricia Bullock who resigned. We are pleased to have Norma Schmidt join us as Senior Secretary

The name of the Fiscal Planning and Budget Office was changed at the end of the year to The Office of Financial Planning and Management. This new name better reflects the mission of the office as it serves MIT's academic and research programs.

JOHN A. CURRIE

Office of Purchasing and Stores

Major projects accomplished or initiated this year include:

- 1) The fully automated, integrated, on-line, and interactive Purchasing, Accounts Payable, and Receiving System became operational in April at all on-campus purchasing offices, research laboratory purchasing agencies and fiscal offices, Accounts Payable, and other administrative offices. The System enables these offices to efficiently and accurately create, print, store, display, and process entire purchase order, invoice, and receiving information on-line.

Beyond modernizing and improving purchasing, payment, and receiving functions, the System that has been developed is part of this Department's plans for providing electronic requisitioning capabilities and electronic access to purchasing information throughout the Institute.

- 2) This Department and the Comptroller's Accounting Office jointly purchased a Digital Equipment Corporation VAX 8550 computer to upgrade and replace a fully amortized and outgrown VAX 785 computer.
- 3) A fully automated, on-line, and interactive Inventory Management software system package was purchased by the Office of Laboratory Supplies (OLS) from Cullinet Software, Inc. The new system will operate on the VAX 8550 computer and will replace an antiquated and inadequate batch process system which operates on IBM VS1 (which IBM and Administrative Systems will cease to support as of December of the coming year). The major features of the new system include order entry and processing, billing of internal accounts, materials handling, perpetual inventory control, and inventory management and replenishment. The system contains other features which will replace tedious and inefficient manual systems. The new system will update, modernize, and expedite processing and materials handling, distribution, and delivery under in excess of 100,000 requisitions annually from the MIT community for items stocked by the OLS. The new system is expected to be ready for implementation in December of the coming year. It is expected that electronic requisitioning for OLS stocked items will be made available later in the coming year.
- 4) The Office of Laboratory Supplies completed the centralization of its receiving by transferring building 3 receiving functions to building N52. This contributed to increased efficiency in the areas of materials handling, storage, and distribution and reduced on-campus delivery vehicle traffic.

General Purchasing Office

Purchasing activity for the year continued at the previous year's level. Of a total 88,000 purchase orders issued by all on-campus purchasing agencies, the General Purchasing Office processed and issued 59,000 or 67 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.

The Graphic Arts Purchasing Office, which is physically located at Graphic Arts, is organizationally an extension of this office, and provides procurement services for the substantial printing, forms and related requirements of Graphic Arts, the MIT Press, and all on-campus departments, centers, and laboratories.

Central Subcontracts and Major Equipment Acquisitions Office

This office was established this year to consolidate, under the Assistant Director for Subcontracting and Government Relations, existing personnel with special capabilities in the areas of high dollar, complex procurement under Federal contracts and grants and with Institute funds. The office extends high level procurement capabilities and service to principal investigators and other requisitioners not associated with the large research laboratories which have in-house purchasing assistance available. The Assistant Director provides guidance and instruction to all purchasing agencies on Federal procurement regulations and contract and grant requirements, and reviews the subcontracts and major purchase orders processed by these agencies to ensure compliance with MIT policies and Federal contract and grant regulations.

The Purchasing Field Office, which provides on-site purchasing and subcontracting services to the Plasma Fusion Center and the Magnet Laboratory, is organizationally an extension of this office.

Office of Laboratory Supplies

Combined sales of office and laboratory items, furniture and furnishings, and personal computers increased 18 percent over the previous year. Sales of office and laboratory items increased 5 percent, sales of furniture and furnishings decreased 18 percent, and sales of personal computers increased 57 percent.

The decrease in furniture and furnishings sales resulted from the reduction of major building renovations and the absence of new building completions this year.

The established Office of Laboratory Supplies' systems for purchasing, receiving, storage, inventory control, delivery, coordination with the Property Office, and internal billing continued to be utilized to support the Microcomputer Center's personal computer resale programs.

Systems Office

This office was established this year to consolidate, under the Manager of Purchasing and Stores Systems, the management and improvement of purchasing function and stores function software and hardware. The responsibilities of this office include the design, development, and implementation of system enhancements and new systems to provide the capabilities for electronic requisitioning and electronic access to system information throughout the Institute, and for other innovative and efficient uses of automated systems and computers. The Manager also performs day-to-day system management of the VAX 8550 computer which is shared by this Department and the Comptroller's Accounting Office.

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. For the first time, the Institute exceeded the \$6.0 million level in awards to minority business concerns, and the \$5.0 million level in awards to woman-owned business concerns. Over \$7.0 million was awarded to 282 minority businesses and \$6.0 million was awarded to 668 woman-owned businesses. Accomplishments this year represent a 30 percent increase over the previous year.

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.

BARRY ROWE

Office of Registration and Student Financial Services

Several significant accomplishments can be recorded for the past year.

In the Bursar's Office, the successful conversion of our loan electronic data processing system to First Wachovia Student Financial Services, Inc. of Winston-Salem, N.C. was completed, and the renovation of the office space, in the planning stages for several years, was begun with a completion date of mid-August.

The Registrar's Office has undertaken a comprehensive business analysis of the Student Information System, employing the Exeter Group as consultants in this effort. It will help us understand where we are now, where we want to be in the future, what computer system best supports those goals, and outline a strategic plan of how we can get there.

The Student Financial Aid Office has successfully implemented the new MIT Opportunity Awards Program. Beginning with the freshman class entering in 1988, this program provides for additional scholarship grants, within need, for the lowest-income registrants, which we hope will result in increased application, enrollment and graduation rates for those students. That office has also developed a new and unique way of implementing the Congressional Methodology (of which we wrote in last year's President's Report) for determining the financial need of each student. Our procedure preserves the integrity both of MIT's own professional approach to need analysis and the federally-mandated system for distributing federal funds.

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 filled five key positions (Associate Bursars/Alumni Services and Student Services, and Assistants to the Bursar/Accounting, Information Systems, and Loan Collection).
- **Federal Regulations:** We reviewed, analyzed, and commenced implementation of extensive new federal regulations governing federal loan programs.
- **Loan System:** We successfully completed conversion of our loan system to First Wachovia Student Financial Services, Inc. of Winston-Salem, NC, with minimum alumni problems.
- **Office Automation:** We integrated a network of Macintoshes into our daily working routine, trained personnel, and are extensively utilizing this resource.
- **Renovation:** We completed planning for the renovation of our office, which is underway and will be completed this summer.

Student Services

We continued our efforts toward more effective communications, through intra- and inter-departmental meetings. We directed more attention to the management of nonregistered student accounts.

Student tuition, fees, and other charges totaling \$137,045,780 were billed, an increase of 4.2% from last year. Servicing the 10,136 student accounts required 229,724 transactions to the student accounts receivable system. Income from late payment fees was \$93,642 and income from finance charges was \$175,483.

MIT's Parent Loan Program (PLP), established in 1977, is an important source of funding for 445 families with 266 active PLP accounts and approximately 45 new borrowers this year. A total of \$2,169,212 was disbursed during the year and \$2,614,869 in principal was collected. The PLP receivable at the end of the fiscal year was \$2,918,634.

Alumni Services

Student loans receivable totaled \$40,852,162 at fiscal year end. These notes were funded by \$13,686,898 of MIT loan funds established by friends and alumni of the Institute; \$19,419,145 of federal funds in support of the Perkins (formerly the National Direct Student) Loan Program; \$83,856 of federal funds borrowed to support a portion of our contribution to the Perkins Loan Program; \$4,562,263 borrowed from the Student Loan Marketing Association; and \$3,100,000 borrowed from local banks.

MIT's default rate on Perkins/National Direct Student Loans was 1.9% in 1987 (compared to 1.1% in 1986); the national default rate for that program also increased over that time from 7.7% to 8.0%, due in part to a change in the federal methodology for calculating default rates. MIT's default rate on Guaranteed Student Loans (GSL and FISL) was 2.0% in 1987 (compared to 2.0% in 1986); the corresponding national default rate increased over that time from 12.6% to 13.1%.

Accounting and Information Systems

This was a year of transition in this area, including major systems and staff changes. The loan system and office automation achievements described above occurred coincidentally with turnover in two of the three administrative staff positions. In addition to these major developments, we have started to convert from VS1 to CMS batch the numerous production, retrieval, and report programs on the SAR system, due to MIT's decision to phase out VS1. Updating of the documentation of the SAR system is under way.

Staff Notes

Cheryl L. Blankenship joined our staff as Associate Bursar/Student Services in September. She came from Los Angeles College of Chiropractic where she was Director of Student Affairs and Financial Aid.

Joseph F. Luszc resigned his position as Assistant to the Bursar/Information Systems in August, to go to the Massachusetts Higher Education Assistance Corporation.

Ann S. McCormick, Assistant Bursar/Loan Collection, retired in May.

Sue H. McKinley joined our staff as Assistant to the Bursar/Accounting & Control in April. She came from Boston University where she was Data Manager/Analyst.

Margaret L. Nelson resigned her position as Assistant to the Bursar/Loan Collection in December.

Geraldine L. Purdy joined our staff as Assistant to the Bursar/Loan Collection in February. She came from United States Small Business Administration, where she was Loan Officer.

Ann Braden Reilly joined our staff as Assistant to the Bursar/Information Systems in January. She came from MIT's Office of the Dean for Student Affairs, where she was Staff Associate for Residence Programs.

Kate Wilson left the position Associate Bursar/Student Services in September to assume the newly-created position Associate Bursar/Alumni Services.

SHIRLEY M. PICARDI, Bursar

STUDENT FINANCIAL AID OFFICE

The Madness in the Methodology

Last year's report introduced the "Congressional Methodology" -- a law that mandates the way federal financial aid dollars are to be meted out to students, beginning in the coming academic year. While this new methodology for doing need analysis did not affect the aid program in 1987-88, the 1988-89 aid calendar began in January of 1988 in most aid offices; so the aid profession has spent most of the past year trying to understand and preparing to implement the scheme. The advent of this incubus upon the aid profession has wreaked far more grief than even the pessimists predicted. Most disturbing is the persistence of the ubiquitous unanswered question -- how will the auditors read the new law five or ten years from now, when it is too late for the schools to retract awards judged then to have been in violation of the statute? The debate over interpretation in several key areas of the law has occupied, preoccupied and exhausted the financial aid community -- primarily because the interpretation has a profound effect on the amount of federal financial aid a student may receive. And many schools have allowed the new system to drive the distribution of their own aid resources as well, compounding the potential effect of changes in the methodology.

From the debate, MIT has forged a new procedure for itself that preserves the integrity both of the new Congressional Methodology and our own long-standing and proven principles of award-equity among all applicant families. The new law has been made a "junior partner" with our own aid program, controlling (as it should) the distribution of federal aid, while the aid office staff continues to determine the distribution of MIT's own funds and the total amount of aid received by a student. We will continue to advocate this approach among the profession as the coming year unfolds.

The Need for Financial Aid

The aggregate undergraduate need for assistance grew again, by \$1,625,000. We assisted 67 more needy students than the target figure for the year, and the average need for help was also a bit higher than predicted. The number of students, 2367, is 7 more than last year, and we are convinced that the several-year drop in this statistic has ceased and it is on the way up again. The average need was \$12,302. In the aggregate, the financial aid program required \$15,684,000 from needy students' family resources, and provided \$29,119,000 in aid dollars. Thus the aid program again accounted for 65% of needy students' total costs.

Scholarships and Grants

The year was marked by another reduction in grants from federal programs, bringing the Government's participation in the scholarship program at MIT below the 15% mark for the first time since the Johnson administration. Shrinkage was recorded in all three federal grant programs -- a drop of 6% (vs. last year's 10%). This was again more than offset by a welcome increase in income from MIT's own scholarship endowment. We were pleased to see scholarship awards made directly to needy students by outside sponsors rise by 6%, correcting last year's leveling-off of this item. Overall, the level of awards from designated grant and scholarship resources passed the 10.5 million dollar point; and was 7.9% higher than last year. These resources once again fell far short of the need, and the program was augmented by \$6,969,000 from unrestricted income, a figure that represents about 12.7% of undergraduate tuition income.

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>1985-86</u>	<u>1986-87</u>	<u>1987-88</u>
Pell Grants	\$ 825,000	\$ 630,000	\$ 665,000
SEO Grants	1,329,000	1,304,000	1,317,000
ROTC Scholarships	840,000	767,000	565,000
Scholarship Endowment@	3,540,000	4,813,000	5,379,000
Current Gifts	800,000	763,000	1,036,000
Direct Grants	1,819,000	1,811,000	1,918,000
<u>Unrestricted Funds#</u>	<u>5,680,000</u>	<u>6,121,000</u>	<u>6,969,000</u>
Total Grants Awarded	\$14,833,000	\$16,209,000	\$17,849,000

@ Net of Draft to Int'l Student Loan Fund.
Including Special Program Grants.

Loans

MIT students continue to enjoy unlimited access to the loan assistance they need. The Perkins Loan Fund (formerly NDS Loans) was used less than last year, a reflection of more aggressive use than of a carryover balance. Still, we were able to award up to \$2000 to each eligible student. Nearly every student with need took a Guaranteed Student Loan as well -- the combination of the two was enough for most. The Technology Loan Fund continues to be the only loan resource for foreign students, and a vital last resort for many U.S. citizens for whom the federal programs are insufficient or unavailable.

Although the variety of loan programs available for students' parents continues to proliferate, the use of these alternatives to cash payment of the Bursar's bills has not grown. The principal reason is deemed to be the removal of loan interest as a tax deduction -- we suspect that most parents with equity in their home are using that last remaining tax-deductible source of loan capital to pay the bills.

The following table details loan use by undergraduate and graduate students:

Loans (received by needy and non-needy students)

<u>Source</u>	<u>1985-86</u>	<u>1986-87</u>	<u>1987-88</u>
A. Awarded to Undergraduates			
Technology Loan Fund	\$ 823,000	\$ 766,000	\$ 735,000
National Direct Loans	2,452,000	2,844,000	2,478,000
<u>Guaranteed Student Loans</u>	<u>5,629,000</u>	<u>4,834,000</u>	<u>5,068,000</u>
Sub-Total	\$8,904,000	\$8,444,000	\$8,281,000
B. Awarded to Graduate Students			
Technology Loan Fund	\$1,396,000	\$1,198,000	\$1,311,000
Guaranteed Student Loans by Commercial Lenders	3,395,000	3,350,000	3,473,000
<u>Guaranteed Student Loans by MIT</u>	<u>120,000</u>	<u>56,000</u>	<u>594,000</u>
Sub-Total	\$4,911,000	\$4,604,000	\$5,378,000

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 \$5.70. The number of students working on campus again showed no change.

The College Work-Study Program allocation increased slightly above the 1986-1987 level and was used entirely to subsidize the on-campus student employment program. Approximately two-thirds of the total 1987-1988 allocation was used to subsidize undergraduate work, and one-third to subsidize graduate student teaching assistantships.

New alien-control laws were passed during the year, that affect every new employee of the Institute. New employees must now present citizenship-verifying material, and the Institute must process paper in connection with the event. The Student Employment Office was heavily involved in the task group that sought the best procedure for compliance; and eventually shouldered the principal burden on behalf of undergraduate students.

Programs of Interest

- Arising from the administration's renewed concern about perceptions held of MIT by prospective students from families with low incomes, a new financial aid program was inaugurated and shaped during the year. Beginning with the freshman class that enters MIT in September, 1988, approximately 125 of the lowest-income registrants will enjoy a significant reduction in the standard "self-help" (loan and job) expectation. The additional relief, seen in the form of additional scholarship aid, is called an MIT Opportunity Award, and 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.
- The SFAO and the Sloan School Master's Program office jointly devised an admissions-process calendar that should provide applicants to Sloan with more timely and complete information about the financial aids available to them.
- During the year, The SFAO put the finishing touches on a process that will monitor and manage the federal Pell Grants electronically. The new process greatly simplifies the paperwork required of both the grant recipient and the Institute.
- Taking advantage of new facilities provided by the Information Processing Center, the SFAO completed its dual-purpose personal computer/mainframe access "netway." The system provides each aid officer with direct access to the Registrar's Student Database for a variety of daily tasks, reducing the extent of dependency upon specialized access programs and people.
- The staff of the SFAO planned and executed an all-day retreat and seminar at Endicott House, in order to discuss our mission and how well we are accomplishing it. Among the useful outcomes was recognition that our direct services to students (the way we handle applications, phone calls, letters and visits to the office; and the means we use to transmit information to students) could be improved at relatively low cost. We intend to concentrate on these improvements during the coming year.

Staff Notes

During the year three administrative staff members were promoted. Jane D. Smith became Associate Director and Director of Student Employment; Lois B. Levine was promoted to Associate Director; and Donna M. Kendall became Assistant Director. Assistant Director Lisa A. Oteri began an extended leave of absence beginning in October of 1987, to pursue her educational program. To perform the duties Ms. Oteri vacated, Katherine M. Nolan (B.A., Wells College) joined the SFAO in February, 1988, as Assistant Director, bringing with her several years of direct experience as a financial aid officer at a number of other fine colleges.

* 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.

LEONARD V. GALLAGHER, Director

REGISTRAR'S OFFICE

Enrollment

In 1987-88 student enrollment was 9,565, compared with 9,756 in 1986-87. This total was comprised of 4,377 undergraduates (compared with 4,443 the previous year), and 5,188 graduate students (compared with 5,313 the previous year). The continuing decline in undergraduate enrollment resulted from a decision by the Institute several years ago to decrease the freshman class size below 1,000 in order to address housing concerns. The International student population was 1,880, representing eight percent of the undergraduate and 30 percent of the graduate population. These students were citizens of 90 countries.

In 1987-88, there were 2,389 women students (1,384 undergraduate and 1,005 graduate) at the Institute, compared with 2,340 (1,295 undergraduate and 1,045 graduate) in 1986-87. In September 1987, 358 first-year women entered MIT, representing 36 percent of the freshman class.

In 1987-88, there were 1,475 minority students (1,236 undergraduate and 239 graduate) at the Institute, compared with 1,344 (1,124 undergraduate and 220 graduate) in 1986-87. Minority students included 292 Blacks (non-Hispanic), 19 Native Americans, 305 Hispanics, and 859 Asian Americans. The first-year class entering in September 1987 included 349 minority students representing 35 percent of the class. Due to changes in Federal guidelines, beginning 1986-87 students with permanent residence status have been included with U.S. citizens, affecting the counts of both International and Minority students.

Degrees Awarded

Degrees awarded by the Institute in 1987-88 included 1,150 bachelor's degrees, 1,056 master's degrees, 49 engineer's degrees, 516 doctoral degrees -- a total of 2,771.

Tabular Presentation

Most of the above 1987-88 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 MIT academic program: negotiating the inclusion of grades received by MIT undergraduates at Harvard College on the MIT transcript; conducting studies to assist the work of various Faculty Committees (e.g., in developing evening exam policy) and fulfilling a wide variety of requests for information and statistics; developing policies for releasing information from the student data base for the purpose of conducting institutional research; developing ways to facilitate the UASO's end-of-term review of the academic progress of freshmen; maintenance of the Classroom Schedule in Lotus format to facilitate the provision of longitudinal data on room utilization; developing ways to provide additional support for Course 6; working out procedures to handle the Registration Day conflict with Rosh Hashanah; preparing a proposal to make significant modifications in the academic calendar; articulating procedures for reviewing/recording the completion of the Writing and Physical Education Requirements.
- Strengthen effectiveness and efficiency in office operations: electronically transferring graduate admissions information to the Registrar's Office; upgrading several systems' modules to improve the Student Information System; completing the local area PC network linked with the mainframe; developing procedures and software to interface our network with the Communications Office for publishing parts of the Catalogue; developing specifications for adding Separation Date to the student database; consolidating the administration of Harvard Cross-Registration; revising Registration forms and procedures at substantial financial savings; updating the Add/Drop card and many other forms; reviewing/documenting the end-of-term procedures leading to Commencement; discontinuing the maintenance of detailed attendance records on noncredit Summer Session subjects.
- Initiate management practices in various areas: personnel administration, organizational structure, revision of all job descriptions, filling of important staff vacancies, review and documentation of office operating procedures.
- Initiate a careful assessment of the capabilities, needs, and strengths -- a major "business analysis" -- of the computerized Student Information System and GASP Scheduling System operated by the Registrar's Office: ascertaining the information and systems needs and expectations of users/potential users and how effectively the current system is set for meeting them over the longer-term; assessing the efficiency of the various programs and how the system interfaces with the paper flow in the Registrar's Office that supports the system; developing a set of recommendations and strategic plan. A request for proposals to assist the Registrar's Office with the analysis was distributed to a number of vendors, and the Exeter Group was chosen.

Important Issues on the Agenda

- Complete the Business Analysis of the Student Information System by Fall 1988, develop a strategic plan, and pursue the acquisition of a separate IBM mainframe for operating the Student Information System in a secure, cost-effective environment. Provide effective assistance and consultation for users of the Student Information System.
- Continue to develop various ways of passing data in electronic form from the Registrar's Office to faculty and departmental offices and vice versa (consistent with adequate provisions for security and privacy).
- Strengthen the academic research capabilities in the Registrar's Office in support of the Institute's educational programs.
- Develop enhancements that make the GASP scheduling system more flexible and responsive to faculty and departmental needs. Complete the effort to rewrite GASP into C language and to update the documentation. Establish a computerized room scheduling book on the PC network. Continue special scheduling efforts in support of the freshman year.
- Work with the Planning Office and Dean for Undergraduate Education on an aggressive renovation program for classroom/lecture facilities at MIT.
- Establish a Registrar's satellite office ("front door") in the main building. Review/strengthen the Office's space utilization and physical working environment.
- Strengthen electronic publishing programs for the catalogue, class schedule, commencement book, diplomas, and Registrar's Office forms/reports.

Staff Notes

Ronald Smith, Associate Registrar, and Isabelle Barclay, Administrative Staff Assistant, retired at the end of the year, each after 19 years of dedicated service to MIT. Dody Gordon was promoted to Supervisor, Records Section, Tom McCormack was promoted to Analyst Programmer III, and Constance Donaghey and Mary Jasinski joined the staff as Assistants to the Registrar. Roberta Welch assumed new responsibilities in the areas of undergraduate degree audit and budget. Anne Wierum and Iria Romano joined the Office as administrative staff assistants.

DAVID S. WILEY, Registrar

CLASSIFICATION OF STUDENTS BY SCHOOL, COURSE, AND YEAR, 1987-88*

COURSE	Undergraduates				Non Res. ¹	Total	COURSE NUMBER
	2	3	4	5			
SCHOOL OF ARCHITECTURE AND PLANNING							
Architecture, IV	36	28	37	266 (8)	11	378 (8)	IV
Architecture, IV-B	3	4	3	-	-	10	IV-B
Urban Studies and Planning, XI	-	3 (1)	1	163 (19)	31	198 (20)	XI
Total	39	35 (1)	41	429 (27)	42	586 (28)	Total
SCHOOL OF ENGINEERING							
Aeronautics and Astronautics, XVI	102	110	93	219 (20)	1	525 (20)	XVI
Aeronautics and Astronautics, XVI-B (Cooperative)	-	-	1	-	-	1	XVI-B
Aeronautics and Astronautics, XVI-C (Internship)	-	11	13	-	-	24	XVI-C
Chemical Engineering, X	39	38	52	237 (2)	-	366 (2)	X
Chemical Engineering, X-C	1	-	2	-	-	3	X-C
Civil Engineering, I	17	20	27	262 (15)	2	328 (15)	I
Civil Engineering, I-A	6	2	2	-	-	10	I-A
Civil Engineering, I-W (Woods Hole)	-	-	-	7	-	7	I-W
Electrical Engineering and Computer Science, VI							
Program 1-Electrical Science and Engineering	186	143	182				
Program 3-Computer Science and Engineering	91	78	74 (1)	631 (69)	-	1,385 (70)	VI
Electrical Engineering and Computer Science, VI-A (Cooperative)	-	60	74	106	-	292	VI-A
Program 1-Electrical Science and Engineering	-	26	26				
Program 3-Computer Science and Engineering	-						
Electrical Engineering and Computer Science, VI-W (Woods Hole)	-	-	-	1	-	1	VI-W
Materials Science and Engineering, III	27	6	14	238 (13)	3	288 (13)	III
Materials Science and Engineering, III-A	1	2	1	-	-	4	III-A
Materials Science and Engineering, III-B (Cooperative)	10	33	37	-	-	80	III-B
Mechanical Engineering, II	132	126	110	422 (39)	-	790 (39)	II
Mechanical Engineering, II-A	8	11	13	-	-	32	II-A
Mechanical Engineering, II-B (Internship)	-	23	29	-	-	52	II-B
Mechanical Engineering, II-W (Woods Hole)	-	-	-	4	-	4	II-W
Nuclear Engineering, XXII	10	6	3	148 (2)	-	167 (2)	XXII
Nuclear Engineering, XXII-A (Internship)	-	3	-	-	-	3	XXII-A
Ocean Engineering, XIII	8	2	1	76 (4)	1	88 (4)	XIII
Ocean Engineering, XIII-C (Internship)	-	-	-	-	-	-	XIII-C
Ocean Engineering, XIII-W (Woods Hole)	-	-	-	19	-	19	XIII-W
Naval Construction and Engineering, XIII-A	-	-	-	59 (1)	-	59 (1)	XIII-A
Ocean Systems Management, XIII-B	-	-	-	9	-	9	XIII-B
Center for Advanced Engineering Study, EN	-	-	-	45 (45)	-	45 (45)	EN
Total	638	700	754 (1)	2,483 (210)	7	4,582 (211)	Total

SCHOOL OF HUMANITIES AND SOCIAL SCIENCE							
Economics, XIV	19	20	23	125 (6)	12	199 (6)	XIV
Humanities, XXI	5	6	15	-	-	26	XXI
Humanities and Engineering, XXI-E	1	5	12	-	-	18	XXI-E
Humanities and Science, XXI-S	5	6	8	-	-	19	XXI-S
Linguistics and Philosophy, XXIV	-	5	5	63	6	79	XXIV
Political Science, XVII	8	8	17	127 (7)	35	195 (7)	XVII
Total	38	50	80	315 (13)	53	536 (13)	Total
SLOAN SCHOOL OF MANAGEMENT							
Management, XV	32	34	56	406 (16)	6	534 (16)	XV
Management Fellows, XV-A	-	-	-	64 (8)	-	64 (8)	XV-A
Management-Operations Research, XV-B	-	-	-	18	-	18	XV-B
Management-Ph.D., XV-P	-	-	-	85	-	85	XV-P
Total	32	34	56	573 (24)	6	701 (24)	Total
SCHOOL OF SCIENCE							
Applied Biological Sciences, XX	-	-	-	86	-	86	XX
Biology, VII	58	57	75	178 (7)	-	368 (7)	VII
Biology, VII-A	2	10	6	-	-	18	VII-A
Biology, VII-B	11	17	11	-	-	39	VII-B
Biology, VII-W (Woods Hole)	-	-	-	19	-	19	VII-W
Chemistry, V	28	26	22	241 (2)	-	317 (2)	V
Earth, Atmospheric, and Planetary Sciences, XII	6	7	17	109 (2)	2	141 (2)	XII
Earth, Atmospheric, and Planetary Sciences, XII-W (Woods Hole)	-	-	-	68	-	68	XII-W
Mathematics, XVIII	29	36	45	140 (9)	1	251 (9)	XVIII
Mathematics with Computer Science, XVIII-C	18	25	15	-	-	58	XVIII-C
Physics, VIII	53	62	66	296 (8)	-	477 (8)	VIII
Physics, VIII-A	26	21	17	-	-	64	VIII-A
Total	231	261	274	1,137 (28)	3	1,906 (28)	Total
WHITAKER COLLEGE of Health Sciences, Technology, and Management							
Brain and Cognitive Sciences, IX	11	17	13	50	-	91	IX
Health Policy and Management, HPM	-	-	-	7	-	7	HPM
Harvard-MIT Division of Health Sciences and Technology, HST							
	-	-	-	83 (54)	-	83 (54)	HST
Undesignated	48	23 (23)	-	-	-	71 (23)	Undesignated
First Year	1,002					1,002	First Year
Grand Total	1,002	1,037	1,120 (24)	1,218 (1)	5,077 (356)	111	9,565 (381)
(Not included in the above totals)							
Non-Institute Harvard	3	19	14	39	209	-	284
Non-Institute Tufts	22	10	13	10	-	-	55
Non-Institute Wellesley	1	50	31	52	-	-	134

* All figures include special students (special students also shown separately in parentheses)
 1 Non-Resident Graduate Students

Not included in above totals:
 7 students in the third year, 2 students in the fourth year on Foreign Study
 2 students in the third year on Domestic Study

ACADEMIC STAFF COUNT

	Professors*	Administration also Professors*	Institute Professors Emeriti-Part Time*	Adjunct Professors*	Associate Professors*	Assistant Professors*	Sr. Lecturers and Professors Emeriti*	Sr. Lecturers	Lecturers	Sr. Research Scientists	Instructors	Technical Instructors	Sr. Research Associates	Postdoctoral Associates	Research Assistants	Teaching Assistants	Instructor Grad	Total	Visiting Professors	Others ¹
Institute Professors	11	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17	1	-
SCHOOL of ARCHITECTURE AND PLANNING																				
Architecture	10	2	-	1	7	5	-	-	17	-	-	1	-	-	11	71	4	129	5	5
Urban Studies and Planning	14	1	-	2	4	5	2	1	4	-	-	-	-	-	40	8	-	81	5	16
Media Arts and Sciences Sect.	4	-	-	-	3	3	-	-	2	-	-	5	-	-	43	-	-	60	4	2
Total	28	3	-	3	14	13	2	1	23	-	-	6	-	-	94	79	4	270	14	23
SCHOOL OF ENGINEERING																				
Aeronautics and Astronautics	1	-	-	-	3	-	1	-	1	-	-	-	-	-	-	-	-	6	-	1
Chemical Engineering	20	3	-	2	6	9	6	4	9	-	-	3	-	1	129	12	-	204	-	8
Civil Engineering	18	2	-	-	5	5	-	1	2	-	1	1	1	7	131	26	-	200	1	17
Electrical Engineering and Computer Science	22	5	-	-	9	5	1	3	4	-	-	-	-	6	152	24	2	233	8	11
Materials Science and Engineering	52	14	-	5	30	15	7	-	9	3	-	4	-	319	115	2	575	4	9	
Mechanical Engineering	17	4	-	2	6	9	4	-	-	-	2	3	17	168	14	-	246	4	34	
Nuclear Engineering	27	1	-	1	18	13	5	8	25	1	-	6	1	7	226	32	-	371	4	22
Ocean Engineering	15	2	-	-	4	1	-	-	2	1	-	-	-	68	18	-	111	-	7	
Ocean Engineering	13	1	-	-	9	2	-	3	6	-	-	-	-	4	52	10	-	100	1	6
Total	185	32	-	10	90	59	24	19	58	5	1	16	5	42	1,245	251	4	2,046	22	115
SCHOOL OF HUMANITIES AND SOCIAL SCIENCE																				
Economics	1	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	4	-	1
Humanities	18	2	-	-	3	5	-	-	-	-	-	-	-	7	24	-	-	59	4	14
Anthropology/Archaeology	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Foreign Languages and Literatures	3	-	-	2	-	-	-	-	5	-	-	-	-	-	-	-	-	10	-	1
History	2	1	-	-	7	2	-	-	18	-	-	-	-	-	-	-	-	30	-	1
Literature	5	2	-	-	4	4	-	-	-	-	-	-	-	-	-	-	-	15	-	-
Music	5	2	-	-	6	2	-	-	8	-	-	-	-	-	-	-	-	23	-	1
Writing Program	5	1	-	-	2	1	-	3	13	-	-	5	-	-	-	-	-	30	-	12
Linguistics and Philosophy	1	1	-	1	2	4	-	-	11	-	-	7	-	-	-	-	-	27	-	6
Political Science	12	2	-	-	2	5	-	1	-	-	-	-	-	24	11	-	-	57	-	20
Program in Science, Technology, and Society	12	2	-	-	5	6	-	1	4	-	-	-	-	47	12	-	-	89	1	1
Program in Science, Technology, and Society	5	1	-	-	2	-	-	-	-	-	-	-	-	1	-	-	-	9	2	25
Total	69	14	-	1	35	29	-	5	62	-	-	12	-	-	79	47	-	353	7	82
SLOAN SCHOOL OF MANAGEMENT																				
Management	33	3	-	1	19	22	2	8	6	-	-	-	1	-	59	63	-	217	13	25
SCHOOL OF SCIENCE																				
Applied Biological Sciences	9	2	-	1	2	4	-	-	3	-	1	-	-	31	53	4	-	110	3	58
Biology	33	3	-	-	4	10	-	1	-	1	-	-	-	46	24	-	-	122	1	84
Chemistry	23	2	-	-	3	3	3	-	1	-	-	1	-	54	150	50	-	290	1	61
Earth, Atmospheric, and Planetary Sciences	18	2	-	-	8	8	1	1	1	2	-	-	-	9	88	17	-	155	4	23
Mathematics	35	1	-	-	7	10	-	1	1	-	23	-	-	2	33	54	-	167	4	22
Physics	59	5	-	-	5	17	2	-	1	12	-	7	-	10	196	40	-	354	2	28
Total	177	15	-	1	29	52	6	3	7	15	24	8	-	152	544	165	-	1,198	15	276
WHITAKER COLLEGE of Health Sciences, Technology, and Management																				
Brain and Cognitive Sciences	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	2	-	3
Brain and Cognitive Sciences	15	2	-	-	7	5	-	-	2	-	-	2	-	7	4	5	-	49	-	45

WOMEN STUDENTS BY SCHOOL, COURSE, AND YEAR, 1987-88¹

COURSE	UNDERGRADUATE			GRADUATE NON-			TOTAL
	2	3	4	REGULAR	RESIDENT	SPECIAL	
SCHOOL OF ARCHITECTURE AND PLANNING							
Architecture, IV	19	17	17	65	3	3	124
Architecture, IV-B	1	2	-	-	-	-	3
Urban Studies and Planning, XI	-	1	1	62	15	7	86
Total	20	20	18	127	18	10	213
SCHOOL OF ENGINEERING							
Aeronautics and Astronautics, XVI	26	20	13	16	-	1	76
Aeronautics and Astronautics, XVI-C (Internship)	-	-	3	-	-	-	3
Chemical Engineering, X	25	19	20	40	-	2	106
Chemical Engineering, X-C	1	-	1	-	-	-	2
Civil Engineering, I	4	3	5	38	-	4	54
Civil Engineering, I-A	3	1	2	-	-	-	6
Civil Engineering, I-W (Woods Hole)	-	-	-	1	-	-	1
Electrical Engineering and Computer Science, VI							
Program 1-Electrical Science and Engineering	56	26	39				
Program 3-Computer Science and Engineering	23	12	9	93	-	12	270
Electrical Engineering and Computer Science, VI-A (Cooperative)							
Program 1-Electrical Science and Engineering	-	12	15	9	-	-	42
Program 3-Computer Science and Engineering	-	1	5				
Materials Science and Engineering, III	14	2	7	58	1	5	87
Materials Science and Engineering, III-A	-	1	1	-	-	-	2
Materials Science and Engineering, III-B (Cooperative)	9	13	19	-	-	-	41
Mechanical Engineering, II	42	30	29	42	-	9	152
Mechanical Engineering, II-A	5	5	4	-	-	-	14
Mechanical Engineering, II-B (Internship)	-	8	12	-	-	-	20
Nuclear Engineering, XXII	3	1	-	17	-	-	21
Nuclear Engineering, XXII-A (Internship)	-	2	-	-	-	-	2
Ocean Engineering, XIII	3	1	-	4	1	-	9
Ocean Engineering, XIII-W (Woods Hole)	-	-	-	2	-	-	2
Naval Construction and Engineering, XIII-A	-	-	-	2	-	-	2
Center for Advanced Engineering Study, EN	-	-	-	-	-	3	3
Total	214	157	184	322	2	36	915

SCHOOL OF HUMANITIES AND SOCIAL SCIENCE							
Economics, XIV	9	7	6	16	-	2	40
Humanities, XXI	1	1	5	-	-	-	7
Humanities and Engineering, XXI-E	-	2	2	-	-	-	4
Humanities and Science, XXI-S	5	2	4	-	-	-	11
Linguistics and Philosophy, XXIV	-	3	2	25	2	-	32
Political Science, XVII	3	1	4	35	11	6	60
Total	18	16	23	76	13	8	154
SLOAN SCHOOL OF MANAGEMENT							
Management, XV	14	9	21	62	2	5	113
Management Fellows, XV-A	-	-	-	5	-	2	7
Management-Operations Research, XV-B	-	-	-	4	-	-	4
Management-Ph.D., XV-P	-	-	-	15	-	-	15
Total	14	9	21	86	2	7	139
SCHOOL OF SCIENCE							
Applied Biological Sciences, XX	-	-	-	40	-	-	40
Biology, VII	36	27	40	60	-	3	166
Biology, VII-A	-	1	1	-	-	-	2
Biology, VII-B	8	8	2	-	-	-	18
Biology, VII-W (Woods Hole)	-	-	-	13	-	-	13
Chemistry, V	17	13	9	57	-	-	96
Earth, Atmospheric, and Planetary Sciences, XII	4	1	10	25	-	1	41
Earth, Atmospheric, and Planetary Sciences, XII-W (Woods Hole)	-	-	-	23	-	-	23
Mathematics, XVIII	13	10	13	18	1	2	57
Mathematics with Computer Science, XVIII-C	6	8	1	-	-	-	15
Physics, VIII	17	13	8	25	-	-	63
Physics, VIII-A	3	5	2	-	-	-	10
Total	104	86	86	261	1	6	544
WHITAKER COLLEGE of Health Sciences, Technology, and Management							
Brain and Cognitive Sciences, IX	7	5	3	13	-	-	28
Health Policy and Management, HPM	-	-	-	2	-	-	2
Harvard-MIT Division of Health Sciences and Technology, HST							
	-	-	-	6	-	9	15
Undesignated							
	15	6	-	-	-	-	21
First Year	358						358
Grand Total	358	392	299	335	893	36	76
							2,389

¹Also included in Classification of Students.
Total undergraduate women 1,384, including 6 special students.

NUMBER OF DEGREES AWARDED IN SEPTEMBER 1987, FEBRUARY 1988, AND MAY 1988

	S.B.			S.M.			M.ARCH. M.C.P.			ENGINEER			PH.D.			SC.D.			TOTAL		
	S E P T	F E B	M A Y	S E P T	F E B	M A Y	S E P T	F E B	M A Y	S E P T	F E B	M A Y	S E P T	F E B	M A Y	S E P T	F E B	M A Y	S E P T	F E B	M A Y
SCHOOL OF ARCHITECTURE AND PLANNING																					
Architecture	-	-	-	-	-	-	1	8	19	-	-	-	1	1	4	-	-	-	2	9	23
Architecture Studies	-	-	-	2	4	28	-	-	-	-	-	-	-	-	-	-	-	-	2	4	28
Art and Design	1	10	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	10	20
Planning	-	-	2	-	-	-	4	4	32	-	-	-	-	-	-	-	-	-	4	4	34
Real Estate Development	-	-	-	34	1	2	-	-	-	-	-	-	-	-	-	-	-	-	34	1	2
Urban Studies and Planning	-	-	-	-	-	-	-	-	-	-	-	-	1	7	6	-	-	-	1	7	6
Visual Studies	-	-	-	1	-	3	-	-	-	-	-	-	-	-	-	-	-	-	1	-	3
Total	1	10	22	37	5	32	5	12	51	-	-	-	2	8	10	-	-	-	45	35	116
SCHOOL OF ENGINEERING																					
Aeronautics and Astronautics	-	5	87	17	18	21	-	-	-	-	-	1	2	8	6	4	-	3	23	31	118
Ceramics	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
Chemical Engineering	-	2	43	3	2	1	-	-	-	-	-	-	6	3	10	1	2	4	10	9	58
Undesignated	-	1	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	3
Chemical Engineering Practice	-	-	-	10	6	15	-	-	-	-	-	-	-	-	-	-	-	-	10	6	15
Civil Engineering	1	3	26	10	16	29	-	-	-	1	2	1	5	4	3	1	4	-	18	29	59
Undesignated	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Computer Science and Engineering	11	12	80	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	12	80
Electrical Engineering	19	22	176	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19	22	176
Electrical Engineering and Computer Science	-	-	-	23	42	98	-	-	-	1	10	10	9	16	28	2	-	2	35	68	138
Electronic Materials	-	-	-	1	1	4	-	-	-	-	-	-	-	-	-	-	-	-	1	1	4
Materials Engineering	-	-	-	-	1	5	-	-	-	1	-	-	-	-	-	-	-	-	1	1	5
Materials Science	-	-	-	1	2	2	-	-	-	-	-	-	-	-	-	-	-	-	1	2	2
Materials Science and Engineering	-	5	42	-	-	-	-	-	-	-	-	-	4	13	16	3	2	5	7	20	63
Undesignated	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Mechanical Engineering	3	8	107	17	33	53	-	-	-	1	4	2	3	15	23	2	1	2	26	61	187
Undesignated	-	-	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13
Metallurgy	-	-	-	1	1	2	-	-	-	-	-	-	-	-	-	-	-	-	1	1	2
Naval Architecture and Marine Engineering	-	-	-	2	1	14	-	-	-	-	-	-	-	-	-	-	-	-	2	1	14
Naval Engineering	-	-	-	-	-	-	-	-	-	-	7	-	-	-	-	-	-	-	-	-	7
Nuclear Engineering	-	1	2	6	11	10	-	-	-	1	1	3	2	7	4	-	-	-	9	20	19
Ocean Engineering	-	-	1	3	5	6	-	-	-	-	-	-	3	4	5	1	1	1	7	10	13
Ocean Systems Management	-	-	-	2	2	3	-	-	-	-	-	-	-	-	-	-	-	-	2	2	3
Polymers	-	-	-	1	-	4	-	-	-	-	-	-	-	-	-	-	-	-	1	-	4
Total	34	59	584	98	141	268	-	-	-	5	17	24	34	70	95	14	10	17	185	297	988

SCHOOL OF HUMANITIES AND SOCIAL SCIENCE																					
Economics	3	-	18	1	1	1	-	-	-	-	5	11	9	-	-	-	9	12	28		
Humanities	1	2	13	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	13		
Humanities and Engineering	3	2	15	-	-	-	-	-	-	-	-	-	-	-	-	-	3	2	15		
Humanities and Science	-	3	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	7		
Linguistics	-	-	-	-	-	-	-	-	-	-	4	-	5	-	-	-	4	-	5		
Philosophy	-	1	5	-	-	-	-	-	-	-	1	1	1	-	-	-	1	2	6		
Political Science	2	1	11	2	4	4	-	-	-	-	3	6	7	-	-	-	7	11	22		
Total	9	9	69	3	5	5	-	-	-	-	13	18	22	-	-	-	25	32	96		
SLOAN SCHOOL OF MANAGEMENT																					
Management	-	-	-	5	18	218	-	-	-	-	3	9	4	-	-	-	8	27	222		
Management Science	4	5	55	-	-	-	-	-	-	-	-	-	-	-	-	-	4	5	55		
SCHOOL OF SCIENCE																					
Applied Biological Sciences	-	-	-	-	1	-	-	-	-	-	6	6	5	2	-	-	8	7	5		
Biochemical Engineering	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	3		
Biology	-	-	-	3	-	-	-	-	-	-	6	7	8	-	-	-	9	7	8		
Undesignated	1	1	17	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	17		
Chemistry	-	2	22	1	1	2	-	-	-	-	7	16	17	-	-	-	8	19	41		
Earth and Planetary Sciences	-	-	-	1	-	4	-	-	-	-	-	-	-	-	-	-	1	-	4		
Earth, Atmospheric, and Planetary Sciences	-	-	12	-	-	-	-	-	-	-	2	5	4	-	-	-	2	5	16		
Life Sciences	1	10	61	-	-	-	-	-	-	-	-	-	-	-	-	-	1	10	61		
Mathematics	2	8	43	1	-	2	-	-	-	-	4	1	14	-	-	-	7	9	59		
Mathematics with Computer Science	1	1	15	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	15		
Meteorology	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	1	1		
Nutritional Biochemistry and Metabolism	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-		
Oceanography	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	1	1	-		
Physics	7	4	69	1	5	2	-	-	-	-	12	12	18	-	-	-	20	21	89		
Total	12	26	239	9	9	14	-	-	-	-	37	47	66	2	-	-	60	82	319		
WHITAKER COLLEGE of Health Sciences, Technology, and Management																					
Cognitive Science	-	-	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12		
Brain and Cognitive Sciences	-	-	-	-	-	1	-	-	-	-	2	2	2	-	-	-	2	2	3		
Harvard-MIT Division of Health Sciences and Technology																					
	-	-	-	-	-	-	-	-	-	-	1	1	1	-	-	-	1	1	1		
Management of Technology																					
Operations Research	-	-	-	-	-	26	-	-	-	-	-	-	-	-	-	-	-	-	26		
Technology and Policy	-	-	-	1	2	6	-	-	-	-	-	-	-	-	-	-	1	2	6		
Transportation	-	-	-	5	11	13	-	-	-	-	-	-	-	-	-	-	5	11	13		
Without Course Specification	-	-	-	3	2	10	-	-	-	-	-	-	-	-	-	-	3	2	10		
	-	-	-	11	9	19	-	-	-	-	-	-	-	-	-	-	11	9	19		
Awarded Jointly with Woods Hole Oceanographic Institution																					
Biology	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	3		
Civil Engineering	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	2		
Earth, Atmospheric, and Planetary Sciences	-	-	-	-	-	-	-	-	-	-	6	4	6	1	-	-	7	4	6		
Electrical Engineering and Computer Science	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-		
Ocean Engineering	-	-	-	-	-	-	-	-	2	-	1	-	-	2	-	-	5	-	1		
Without Course Specification	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1		
Grand Total	60	109	981	172	202	614	5	12	51	7	17	25	99	159	211	20	10	17	363	509	1,899

Office of Sponsored Programs

For fiscal year 1988, the total volume of sponsored research performed on campus approximated \$269,394,000. This represents an increase of only 2.5 percent over fiscal 1987 volume of \$262,754,000, the smallest year-to-year increase in over ten years. (These figures differ somewhat from those shown in Schedule A of the Report of the Treasurer due to year-end appropriations and adjustments.)

As indicated in the table, total Federal agency sponsorship increased by 1.8 percent, the Department of Health and Human Services (DHHS) by 3.7 percent, the Department of Defense (DOD) by 3.1 percent, the National Science Foundation (NSF) by 2.9 percent, and the Department of Energy (DOE) by only 1.0 percent. National Aeronautics and Space Administration (NASA) funding decreased by 1.6 percent.

The most significant aspect of non-Federal sponsorship is the decrease of 3.5 percent in industrial funding, which continues the downtrend from increases of 40 percent in 1984, 21 percent in 1985, 8.5 percent in 1986, and 1.9 percent in 1987.

CAMPUS RESEARCH VOLUME BY SPONSOR - 1982-1988

(in thousands of dollars)

<u>FEDERAL</u>	<u>1982</u>	<u>1983</u>	<u>1984</u>	<u>1985</u>	<u>1986</u>	<u>1987</u>	<u>1988</u>
DOE	46,283	48,271	51,489	56,363	54,511	55,062	55,629
DHHS	30,911	30,870	36,324	40,252	45,735	47,310	49,070
DOD	27,429	31,883	34,626	38,578	43,418	45,418	46,836
NSF	29,776	31,003	30,876	33,658	36,772	38,091	39,177
NASA	11,053	10,445	11,888	12,315	12,864	12,706	12,509
Other	11,811	10,400	9,783	8,863	7,823	8,238	7,283
Federal Subtotal	157,263	162,872	174,986	190,029	201,123	206,825	210,504
<u>NON-FEDERAL</u>							
Industry	19,696	19,753	27,686	33,456	36,290	36,601	35,315
Nonprofit	11,699	13,196	15,743	15,282	15,532	15,319	19,779
Other	3,312	3,452	3,166	2,958	3,151	4,009	3,796
Non-Federal Subtotal	34,707	36,401	46,595	51,696	54,973	55,929	58,890
<u>TOTAL</u>	191,970	199,273	221,581	241,725	256,096	262,754	269,394

SIGNIFICANT DEVELOPMENTS

As in past years, a variety of external developments, both continuing and new, had an impact on sponsored research programs. Among these were the following:

Restrictions on Scientific Communications

Efforts by Federal agencies to restrict the flow of scientific information to foreign countries and nationals continued in a number of forms.

A few DOD activities attempted during the year to impose publication and other restrictions on DOD funded research involving so-called "critical" but unclassified technology, but this occurs much less frequently now that "fundamental" research has been exempted from such controls.

DOD regulations concerning the imposition of restrictions on the presentation of scientific papers at professional society meetings were issued in October. They responded favorably to university concerns with respect to papers representing the results of fundamental research performed at universities.

During the year, however, several Federal agencies identified specific programs as manpower development programs and made their award contingent on agreement that only U.S. citizens would receive direct funding from them. A number of universities have accepted this limitation on those specific programs on the condition that the participation of foreign nationals funded from other sources is not affected.

In a related development, the General Accounting Office released in March the results of its survey of foreign funding of research at selected universities, including MIT. It found that R&D sponsored by foreign sources accounted for only 1 percent of all university R&D expenditures and that only five universities account for about half of those funds. Foreign sponsorship of MIT research constituted less than 2 percent of its total on campus research volume in fiscal 1988.

Federal Rights-in-Data Policy

We noted in last year's report that an Executive Order on Facilitating Technology Transfer mandated the development of a government-wide policy which would provide for contractor ownership of technical data and software generated on Federally funded research. This policy, in conjunction with contractor ownership of patents as now provided by statute, would substantially improve the effectiveness of university technology licensing programs.

The implementing regulations, as proposed by the major Federal agencies toward the end of the year, however, are primarily directed at the competitive procurement of hardware by industrial contractors and do not address the needs of universities per se. Whether this can be remedied before the final regulation is adopted is not clear.

Other Regulatory Developments

Congress and the Federal agencies continued in fiscal 1988 to focus on issues related to so-called "academic fraud" or "misconduct in science." In April, two congressional committees held formal hearings on scientific fraud. One of them concentrated on several alleged cases of misconduct involving universities in the Boston area. It used the hearing to castigate NIH for its policy of permitting self-regulation by grantee institutions and put pressure on NIH to publish rules defining how it will exercise oversight in such matters.

Legislative activity directed at controlling the use of animals in research continued during the year at both the state and Federal level. Pending at the end of the year in the Senate was the Pet Theft Act, which had the objective of protecting pet owners while at the same time not unreasonably restricting the use of random-source animals in research.

Last year's report cited the proliferation of statutes and regulations designed to curb procurement abuses and ensure competition in defense contracting, which has a spill-over effect on research contracts with universities. The most significant additions to the list during fiscal 1988 were the final government-wide regulations published in May concerning the debarment and suspension of Federal grantees, which parallel those issued earlier for Federal contracts.

Tax Changes

During fiscal 1988, a House Ways and Means subcommittee began examining proposals to change the tax law relating to unrelated business income, which would impact on a variety of university activities. It appeared at the close of the year that the committee would preserve the exemption for research activities as well as the exemption for royalty income derived from exempted research, such as that generated by MIT's technology licensing program.

In 1987 Congress took no decisive steps to clarify and extend legislation concerning the taxability of salaries/stipends and tuition remissions/benefits received by teaching assistants and by graduate students employed as research assistants on sponsored programs. Consequently, university representatives continued throughout fiscal 1988 their efforts to reduce the confusion and uncertainty which remained.

Administrative Simplification

For several years, five Federal agencies and the state colleges and universities in Florida have been collaborating in an experiment intended to streamline the management of Federal grants. In May a number of the features which had proven most successful in that experiment were authorized for use by all Federal agencies. During the year, the Public Health Service also simplified various requirements under its prior approval program and gave grantee institutions increased authority for approving administrative actions.

Universities nation-wide were invited in June to participate in Phase II of the Florida Demonstration Project. It is designed to test the efficacy of standardizing and simplifying the financial and administrative requirements of grants management and to evaluate its applicability to contracts.

DOD Funding Freeze

In May the Deputy Secretary of Defense ordered deferral of all DOD "discretionary spending" because the expenditure rate in DOD had increased substantially beyond predictions and at a rate which would violate the budget summit agreement outlay targets. Specifically targeted for deferral were all new research, development, test and evaluation contracts. In late June, the deferral expired but the average level of obligations for the final quarter of the federal fiscal year was limited to 75% of the average for the prior three quarters. The impact on MIT was not substantial, although at year-end uncertainty remained whether several anticipated awards would be cancelled or be deferred until the start of the new Federal fiscal year on October 1.

Howard Hughes Medical Institute Collaboration

In February, MIT and the Howard Hughes Medical Institute (HHMI) announced a long term collaborative agreement to conduct research in the biomedical sciences at MIT and the appointment of three outstanding MIT scientists as HHMI investigators. HHMI will provide full salary support and funds for part of the research of the investigators, who will continue to teach and function as MIT faculty members. In addition, HHMI has provided \$15 million toward the construction of a planned new research building on the MIT campus in which some HHMI investigators will eventually have laboratories.

Personnel Changes

The following personnel changes occurred during 1988: Jean Weidemier transferred to the Technology Licensing Office on July 14 and John Hynes to the Office of the Vice President for Research on September 6, while John Mahoney retired as of October 31. Barbara Greene joined OSP as Intellectual Property Coordinator on July 8, Jeanne De Pass as a Contract Administrator on November 8, Tony Favaloro as a Contract Administrator on December 1, and Clifford Goodridge as Assistant to the Contract Administrator on October 26.

GEORGE H. DUMMER

VICE PRESIDENT FOR INFORMATION SYSTEMS

For the past several years, the Information Systems Report to the President has indicated that developments in Information Systems (IS) have proceeded at a very rapid pace. This year has been no different. This is inevitable in a field where the price performance ratio of hardware is improving at anywhere from 25 - 40% per year with no end in sight and the use of computers and communication is becoming ubiquitous.

Significant changes in the Institute's information systems environment during the year included:

- Conversion of Project Athena's services from time sharing to workstations. Today Athena operates some 750 workstations distributed across the campus in public and departmental clusters, living groups, and individual offices.
- Continued growth of the Institute's distributed computing environment outside of Athena as evidenced by the sale of microcomputers in IS's Microcomputer Center - some 2200 systems were sold during the year - and by an increase in the number of computers on the campus computer network to a total of 1256.
- Work on the installation of the new telephone system, an AT&T 5ESS digital PBX, continued at a rapid pace with completion of a totally new cable plant and installation of the switch hardware and software. The system will be placed into service in two phases beginning early in fiscal 1989.
- The VAX Resource Center completed its first year of operation providing access to Digital Equipment Corporation's software library, discounts on Digital's hardware maintenance service, as well as installation and consulting services. Approximately half of the campus' Digital hardware maintenance agreements are through the Center providing significant cost savings to MIT.
- The Microcomputer Training Laboratory also had its first anniversary late in the year. Operating at full capacity for the year, it provided hands-on training for approximately 1000 course registrants. In addition, a number of Institute organizations used the facility to present their own training programs.
- Multics computing services ended on January 1, 1988 after a period of over 18 years of operation on a succession of hardware platforms.
- Further steps were taken towards the distribution of responsibilities for development, maintenance, and support of administrative computing activities from IS to the central administrative clients. By the end of fiscal 1988 the Comptroller's Accounting Office had assumed total responsibility for their systems.

Work on the Strategic Plan for Administrative Information Systems continued during the year. Of particular note are the work of the Administrative Workstation Committee to maintain the standard defining the supported hardware and software environments for decentralized administrative computing, the development of a general platform (MIDAS - MIT Information Distribution and Access System) to distribute administrative data from the central databases to departments and laboratories, a study of central administrative computing costs, and the use of functional analysis as a routine step in the development of information systems for offices.

Work in the area of information security was also begun under the auspices of the Strategic Plan. The object of this campus-wide project is to develop a program that will balance the need for open access to, and the availability of information with the requirement for ensuring its reasonable use and protection. This work is being led by Gerald I. Isaacson, a nationally known information security consultant, and will continue over the next several years.

One of the major concerns of IS over the past year has been the community's view of the quality of its services and whether these services were properly focused. This has led to a number of activities aimed at improving the services we deliver to our clients. Among these is the development of service level agreements with many of our major clients. These agreements, which address software development, software maintenance, or the delivery of computational resources, are formal statements between the service provider and the client which set and communicate expectations and responsibilities.

We have also introduced an extensive staff and management performance appraisal process. This process was designed to identify strengths and weaknesses, to assist in the definition of goals, and to set learning and training objectives for the staff and managers.

As a further step in improving our service to the MIT community, we are moving the Microcomputer Center and PC Support to a new facility in the Student Center and consolidating hardware purchasing, repair, and merchandise storage there.

Many of these as well as other activities of the departments are detailed in their separate reports.

Personnel

IS continued its commitment to affirmative action during the 1987-88 year paying particular attention to identifying under-represented minorities in searches to fill vacant positions. Success, however, was meager. Emphasis will continue to be placed on the identification of minority individuals for entry level positions where they can learn the skills required for more advanced positions. To increase our chances of success, we are now informing selected minority placement agencies of all of our openings. IS has continued to identify and attract a number of highly qualified women to its staff. At the present time, almost half of our professional staff are female.

At the end of the year, William F. Hogue, Assistant Director of Project Athena and Director of the Athena Support Group, an organization which crosses the organizational lines of Project Athena and IS, announced his resignation to become Director of Academic Computing at Vanderbilt University.

JAMES D. BRUCE
CECILIA R. d'OLIVEIRA

ADMINISTRATIVE SYSTEMS DEVELOPMENT

During fiscal 1988 Administrative Systems Development (ASD) underwent major changes that are among the first steps in its evolution to an organization that is more responsive to its clients' needs. With the creation of ASD and Architecture and Strategic Technology from the previous Administrative Systems organization, ASD assumed responsibility for providing the Institute's administrative activities with quality, cost effective services and data resource management support to satisfy overall business needs. Much time and energy was spent during the year in putting into place the organization, practices, and people required to assist our clients in meeting their needs. In addition, some important milestones were achieved on projects underway in conjunction with our clients.

Procedures were put into place during the year to capture, record, and report information related to the labor and other costs associated with software development projects. For the first time, accurate and timely data were available to track project costs, and how these costs were distributed among the various categories of service offered. This information was used by ASD management and clients to monitor the effectiveness and efficiency of project efforts. In addition, ASD developed project management guidelines that are being implemented on each project. This provides a consistent methodology for managing all projects within the organization.

Other department-wide changes made during the year include:

- A business analysis function was created and an experienced analyst was hired to assist our clients in clearly identifying their system development requirements.
- Agreements formalizing the partnership between the ASD project teams and the client project managers were developed to improve communications between and efficiency of both parties.

On the project front, several notable milestones were achieved:

- The first, and most important, module of the new Physical Plant system was completed. This module, one of the first designed and implemented at the Institute on a distributed minicomputer utilizing a relational database management system, will allow Plant personnel for the first time to enter, query, and report on work order information on-line.
- ASD completed successfully its changes to the Alumni, Donor, Development, and Schools (ADDS) system in support of the Campaign for the Future. This work provided personnel in Resource Development and the Alumni Association with new tools to use in the fund raising and alumni management functions of the campaign.
- For the first time, the number of transactions processed against the central administrative databases supported by ASD was roughly one billion, an increase of some 25% over fiscal 1987. This is an indication of the increasing usage of the ASD-supported applications by client departments.

During fiscal 1989, ASD will begin to formally charge for the bulk of the services provided to clients, as a move towards increased accountability for the work it performs. The changes made in fiscal 1988, as well as the progress achieved on major projects, have helped to shape ASD as an organization that can respond efficiently and effectively to meet the needs of its clients. With similar progress next year, ASD will continue in its quest to be an important provider of services to help meet the administrative needs of the Institute.

DONALD E. HELLER

ARCHITECTURE AND STRATEGIC TECHNOLOGY

Architecture and Strategic Technology (AST), a new unit of IS, was formed in July 1987 as a focal point for some of the efforts to evolve the coordinated computing environment proposed in the Strategic Plan for Administrative Information Systems. With the diffusion of information technology, managers, work groups, and business units throughout the Institute are all involved with planning, building, and running a wide variety of information systems. Yet, people need some systems to share data and processing more readily. Many systems also have certain support needs in common, such as identifying authorized users and providing backup and recovery.

AST's mission is to provide leadership in establishing a framework for coordinating information resources, so that the needs for sharing and for common support services can be effectively met in the 1990s. The framework includes statements of direction, policies, procedures, standards, controls, services, and tools that are produced collaboratively and communicated broadly. The aim of coordinated computing is to give administrators ready access to the information they need to do their jobs, including criteria for decisions about hardware and software that accommodate both local and institutional priorities.

The new unit established its offices in Building E32 this fall with a small staff drawn from the Administrative Systems organization. This year, AST staff concentrated in three areas on products that will serve as a basis for further collaboration and communication in 1989:

- **Distributing Administrative Data:** Building on work done in pilot projects of the Strategic Plan, AST developed the first release of a data distribution service called the MIT Information Distribution and Access System (MIDAS). The automated service receives data and applications from a central department for distribution to many other offices. It secures the data and transforms them into formats usable on administrative workstations in departments, laboratories, and centers. The initial release of MIDAS is being tested by the Comptroller's Accounting Office, which is providing accounting data and applications, and by a small number of department administrators. If tests are successful, MIDAS will be made available to other central offices and department administrators as a new IS service.
- **Methodology for Application Development:** After AST's investigation, IS acquired a license to use a methodology called Productivity Plus to implement applications for the Institute. A methodology is a systematic set of procedures people use to achieve a desired result – in this case better systems, built more efficiently and easier to maintain. Productivity Plus, which incorporates proven techniques for system analysis and design, covers both development and package acquisition. It can be supported by a variety of CASE (computer-aided software engineering) and project management tools operable across the range of MIT's hardware and software platforms. AST is now engaged with ASD to introduce Productivity Plus in an initial project and to produce a plan for extending its use to other projects and by other departments.
- **System Architecture for Coordinated Computing:** Work has focused on refining expectations for architecture and for coordinated computing. Information systems architecture is an emerging discipline to assist managers in determining how to integrate complex technologies and how information systems will support the business. This year, using prototypes of what coordinated computing might look like to different users, AST conducted first-round discussions with key administrators and devised preliminary statements of the system architecture in the draft edition of a Reference Guide. The aim of the Reference Guide is to describe the major components of the target computing environment and the principal work elements necessary to reach the target. The draft will serve as a basis for provoking deliberations within IS and refinements as we prepare for the Guide's publication and use.

MARILYN A. MCMILLAN

INFORMATION SERVICES

Information Services continued to expand its range of products and services this year.

The Microcomputer Center experienced a period of rapid growth. In the past 6 months we have served over 3,000 students, faculty, and staff representing virtually every part of the MIT community. Gross sales for FY88 are expected to exceed \$7 million. To accommodate this growth we are consolidating operations that have previously been handled in other departments, including hardware purchasing, repair, and merchandise storage. Our planned move to a newly renovated facility in the Student Center building in the fall of 1988 will allow us to perform all our functions under one roof, and provide us with an opportunity to provide new and better services.

Training Services added a Microcomputer Trainer to the staff which allowed us to initiate Administrative Work Station (AWS) training, including Institute Business Modules (two-hour courses designed to teach staff how to accomplish an MIT-specific administrative task by computer), and offer customized courses for individual departments at their site or ours. Training Services completed its first full year of operating the Microcomputer Training Lab. Throughout the year we provided over seventy introductory and advanced hands-on courses, access to the Training Lab for MIT departments to present their own training programs, and more than fifty seminars on computing topics.

Consulting Services has taken on many new areas of responsibility including support of VAXs, supercomputers, LANs (Local Area Networks), and the AWS. A mission statement was developed to define the group's role within IS and within the MIT community. A help line staffed by a full-time receptionist was established. Consultants are being assigned as client representatives to departments which purchase Administrative Workstations. The Requirements Analysis Working Group was established to conduct requirements analyses of the business and technological needs of an office or department. Service packages for Desktop Publishing and LANs have been developed describing the type of service provided.

The VAX Resource Center (VRC) completed its first year of operations, providing access to Digital Equipment Corporation's software library, discounts on DEC's hardware maintenance contracts, as well as installation and consulting services. By year end approximately half of the non-Athena Digital hardware on the campus had maintenance agreements through the VRC.

Publications Services concentrated this year on documentation for microcomputers and on marketing materials for IS. Among the major projects supported were the AWS and the VRC. Two new memo series were initiated: Quick Guides, typically one page of directions for advanced microcomputer functions; and Reprints, articles from current magazines and newsletters. Ten issues of the *i/s* newsletter were produced. Throughout the year staff assisted in the Training Lab and gave presentations and seminars.

STEPHEN M. BAYLE

OPERATIONS & SYSTEMS

The activities of Operations & Systems (O&S) this year included a large variety of tasks which were performed to enhance the services provided to the client communities.

New hardware installed included a NCR Comten 3695 communications processor which provides improved access to the IBM computers. As part of this project, a higher speed 3174 controller and new terminals were installed in the public terminal room in building 11. Also installed in W91 was a Digital Equipment Corporation (DEC) VAX 8530 which will provide a platform for a new Physical Plant system. The conversion of Project Athena to a workstation environment was completed.

The Multics system was phased out of service on January 1, 1988. Developed in the mid-sixties at the Institute by individuals from MIT, Bell Telephone Laboratories, and General Electric, Multics' original objective was to explicitly define all of the desirable features of an idealized time-sharing system as well as building a system that would encompass these capabilities. It was highly successful in achieving these goals and served as a model for many operating systems, including Bell Lab's UNIX™.

Many of the activities of the IBM systems programming group (SPG) were geared to improve services for the administrative client community and to improve the communications capabilities for all clients. Significant progress was made in conjunction with ASD and Information Services to phase out the usage of the VS1 operating system. To accomplish this, SPG developed enhancements to the CMS and CMSBATCH systems to provide comparable functions to those offered by VS1. The VMSECURE package ago was further tailored to improve the level of security offered on the IBM systems.

To improve the data connectivity between the IBM systems and the campus computer network, a new IBM 3282 LAN channel station was obtained and a new version of IBM's TCP/IP code installed. This provides complete access to the ARPAnet community for the users on the IBM 4381.

Production Services (PS) has continued its work to improve the services offered to the administrative client community. In cooperation with Operations and Telecommunications, a problem tracking system was implemented to improve the handling of reported problems accessing the computer systems in W91. This, coupled with the new equipment, has greatly improved the reliability of this service.

An effort was started to improve the system of charging for the use of the IBM computers. This resulted in a new rate schedule which has simplified the basic rate structure and reduced the average costs to the clients. New rates became effective on June 27, 1988. A new bill which combines the charges from all three IBM mainframes will be available in August. Also, other chargeback mechanisms continue to be investigated.

ROGER A. ROACH

TELECOMMUNICATIONS SYSTEMS

On December 11, 1985, MIT and AT&T entered into a contractual agreement that called for AT&T to engineer, furnish and install a 5ESS switching system at MIT. On August 12, 1988 the system will be placed into service to provide telephone service to dormitory residents. Later in the fall service from the 5ESS will be extended and will replace the Institute's present Centrex service.

The 5ESS represents leading edge information age technologies and is compatible with existing telecommunication standards and including the new digital standards for ISDN (Integrated Service Digital Networks). It can be used in analog, mixed analog/digital, or completely digital networks. When placed into full service this fall it will be connected to external switched networks by 1,255 trunks and be capable of serving 14,455 stations -- of which 5,355 will be ISDN stations -- making the MIT 5ESS the largest ISDN system in the country at that time.

Students will have flat rate residential service in their dormitory rooms as well as MCI service for their toll calls. MCI will bill the students directly for these calls.

MIT 5ESS internal rate schedules were published following discussions and reviews with departmental and laboratory administrators as well as senior members of the Institute's administration. The rate schedules are based on a simple scheme in which users are charged for electing either analog or digital service. Rates are to be held constant for a four year period and then adjusted.

Training of the MIT community on the 5ESS system was initiated in 1987. Since then 2,131 members of the staff have attended training classes designed to introduce the use of the new digital technology. Classes on data communications and voice mail services will begin early in fiscal 1989. MIT's voice mail service is based on an Octel Aspen Maxum system, which will provide basic telephone answering service as well as a number of enhanced services. The community of voice mail users is initially forecasted at 1,500.

MIT has acquired a license for a computer-based telecommunications facilities management system, to be integrated with the 5ESS system. The system - ICE-9 (Integrated Communication Environment with 9 modules) - is a product of Auxton Computer Enterprises, a division of Cincinnati Bell Information System, Inc. ICE-9 will replace the TCM billing system which was developed internally some sixteen years ago.

The number of hosts on the campus computer network has increased to 1,256. During the year a pilot network-based electronic mail service was offered to clients with IBM PCs. During fiscal 1989 the pilot will be extended to Apple Macintoshes and become a network service available to the Institute community. Significant software enhancements were also made to the network. Work was also done on the Kerberos Authentication System, which will be used to authenticate network messages used to control the gateway system deployed at MIT.

Staff from the campus computer network group participated in external organizations working towards developing national and international standards. These include the working groups on the Open Interior Gateway Protocol and the Open Internet Network Operations Center.

A path survey was made to determine the physical path and design parameters of a microwave link between MIT campus and the Lincoln Laboratory. The proposed link would be interconnected to an existing microwave link between Lincoln Laboratory and the MIT Westford Sites. Funding is being sought so that the link can be built in fiscal 1989.

The MIT video network was put to innovative use in August 1987 distributing an interactive video teleconference to Sao Paulo, Brazil. The network will also be used to distribute signals received from a Ku-band satellite downlink now being installed on the roof of building 9. This work is a joint effort of with the Center for Advanced Engineering Study (CAES). In addition, the video network was expanded throughout the campus.

The MIT 5ESS universal wiring scheme consists of two 4-pair twisted pair telephone wiring in most work and living areas. One 4-pair is used directly with the 5ESS with the second 4-pair available for use with local area networks (LANs). During the year campus network connections and point-to-point facilities were installed in some 400 new locations.

MORTON BERLAN

SENIOR VICE PRESIDENT

This year the Institute continued its commitment to energy conservation and associated cost avoidance by initiating work on a formal retrofit program in conjunction with Cambridge Electric Light Company's electricity conservation rebate program. Over the next year, we anticipate carrying out \$3.7 million of construction that will touch almost every room on campus. Installation of new, more efficient electric devices, controls, motors, and lighting equipment will generate savings and rebates with a value of over \$1.5 million annually. Since this is a shared savings program, the Institute's net energy cost reduction for the first three years of the program will average approximately \$500,000 per year. Beginning in 1993, essentially all of the savings will be available for other purposes.

Significant progress was made this year on two important campus environmental health and safety issues; namely, the identification and removal or encapsulation of asbestos-containing materials and the identification and removal of polychlorinated biphenyl (PCB)-containing electrical equipment. In addition, a renewed effort was undertaken to clear corridors of all obstructions. The Safety Office, with the help of Physical Plant, the Property Office, and departmental and laboratory personnel, completed a highly successful campus-wide corridor clean-up prior to year end.

Major design and construction activities this year included significant progress on the renovation of the Julius A. Stratton Center, scheduled to re-open next fall; the design of an addition to Building 7 that will allow for expansion of the Rotch Library; and preparatory work for the design and construction of a new biology building on a portion of the former TRW/Carr Fastener site. In addition, preliminary design has been completed for the renovation of 143 Albany Street into housing for 185 married and single graduate students. Construction is scheduled to begin on this project early next fall.

Affirmative action efforts continued this year. Departments were again asked to summarize their affirmative action plans with specific emphasis on efforts to be implemented in attracting minority and women candidates. Partially due to these efforts, we did succeed in hiring two women for positions traditionally held by men, both in the Physical Plant. One is a locksmith and the other a first-class firer in the Utilities Plant. We cannot report having as much success in attracting minority applicants; however, we will continue to look for ways to attract and hire underrepresented minorities.

Following are individual department reports.

WILLIAM R. DICKSON

Campus Activities Complex

The primary focus for the Campus Activities Complex this year was the implementation of renovation plans developed for the Julius A. Stratton Building. Renovation of the Stratton Building began last year and is expected to be completed early in the fall of 1988. Temporary locations for Student Center offices, retail tenants, and student services were established on the fourth and fifth floors of the building allowing for continuous service to the community throughout the construction period.

The leasing of the commercial space formerly occupied by the MIT Coop was met with enthusiastic interest from outside retail businesses. A retail consultant was retained to assist in leasing and rendering advice concerning retail operations, tenant fit-up, and reopening activities.

In other areas, the department expended considerable effort in support of major Institute events. These functions included the opening events associated with the Campaign for the Future; the Dedications of the Green Center for Physics, Killian Hall, and the Johnson Athletics Center; as well as the Draper and Killian Memorial Services.

The department participated in a variety of discussions about the role of the Chapel at MIT. During the coming fiscal year, the Campus Activities Complex will be providing updated services in support of weddings in the Chapel and will be active in promoting community awareness about the MIT Chapel and its related activities.

Lastly, in conjunction with the Office of the Dean for Student Affairs, the Campus Activities Complex finalized plans to implement the last steps in staff and program reorganizations in the Stratton Building. Concurrently, an ad hoc group of students, faculty, and staff was organized to develop the charter and serve as the founding membership of a board for the Activities Complex. Recommendations on mission and composition of the advisory board are nearing completion and will be submitted for review near the time of the reopening of the Student Center.

STEPHEN D. IMMERMANN

Campus Police

In 1987, the MIT Campus Police Department continued to serve the MIT community with 24 hour professional police and emergency medical services. In addition, the Crime Prevention Unit and Special Services Division continued to assist the MIT community by providing crime prevention education; informal legal advice; and assistance for minor legal problems of extenuating circumstances such as tenant/landlord disputes, consumer fraud, small claims court cases, abuse, and harassment situations.

There were a total of 1,492 complaints (situations which required the recording of an incident by police report) recorded this year, a 22 percent decrease compared to last year. Of these 1,492 complaints, 29 were in the crimes against the person category. Campus Police Officers made 81 arrests on MIT property this year.

Larceny continued to be the largest category of crime with which the Institute had to contend in 1987. Although Institute property dollar losses were up 212 percent to \$273,467 (because of thefts of personal computer systems) personal property losses (non-residence) went down 32 percent for a total dollar loss of \$23,316. Residence Hall losses were down 57 percent to a total dollar loss of \$15,946.

Motor vehicle thefts increased slightly this year, rising 5 percent, for a total of 20 vehicles stolen.

Emergency medical service runs decreased 16 percent in 1987, for a total of 2,349 runs (including emergencies, transfers, and medical shuttles).

The Campus Police escort service provided 6,195 escorts in 1987, a decrease of 28 percent compared to last year.

The MIT Campus Police Department looks forward to continuing to provide the MIT community with professional police and emergency medical services in the coming years.

ANNE P. GLAVIN

Endicott House

Several physical changes were made during the year including the relocation of the front office to a more visible area. Subsequent redesign of this space, including the building of a counter for guest registration, installation of cash and safe deposit boxes as well as other guest accommodations has improved the professionalism of the office and the overall efficiency of the operation. In addition, the Conference Services and Sales Offices have been combined in one area to give maximum assistance to customers.

Marketing continues to play a prominent role, with the major effort being directed toward increasing residential business. Surveys have been conducted to insure we keep up with our competition both in terms of pricing and services offered. Two amenities not currently offered at Endicott House are air conditioned accommodations in the main house and an adequate exercise/fitness facility.

Last year, after several attempts, Endicott House was granted a liquor license. The additional revenue generated is being used to offset our increasing operating expenses.

Several changes in equipment occurred during the year. A fully computerized accounts receivable billing system was developed. Various telephone systems were also investigated with the Telecommunications Office in anticipation of replacing the existing system which has proven inadequate for our needs. An analysis of the available equipment, its capability, and related costs is underway.

Funding for capital improvements continues to present a major challenge. During the year, the main house lightning rod system was replaced; asbestos was removed; driveway lighting posts were replaced; new membrane roofing was installed on the flat roof portion of the main house; the residential wing of Brooks Center was stained; the Stearns barn was re-roofed; improvements were made to the main drive storm system; and a commercial hot water storage/heater tank was installed; along with the normal painting, mechanical, and electrical system repairs required on a daily basis.

Statistically, Endicott House continues to have high utilization from both within and outside of the Institute. Throughout the year, Endicott House and adjoining Brooks Center were used 254 days and 179 nights by 196 different groups. This compares with 270 days, 198 nights, and 173 groups last year. Of these groups, 71 were MIT affiliated compared with 56 last year. There was a total of 33 resident groups ranging from a one night stay to the nine week Senior Executive Program. Of these, 20 were MIT affiliated groups. There were 28,753 meals served and 7,301 room nights utilized for a 55 percent occupancy rate.

HOWARD F. MILLER

Graphic Arts and Audio Visual Services

Total income for all Graphic Arts services, including Audio-Visual and Video Productions, increased five percent this year. There were no significant increases (or decreases) in any of the individual departments as in prior years.

Because of space problems at its location in the Wiesner Building (E15), Video Productions was moved to the second floor of the Graphic Arts Building (N42). This is expected to be a temporary move until a permanent location can be found.

Several pieces of new equipment were purchased, including the Linotronic 300, a new state-of-the-art typesetting system. The L-300 is a true "imagesetter," which means it can print standard type forms as well as complex graphics composed of lines and shading. Used in conjunction with a Macintosh II computer, it can handle text file transfers from virtually any system and produce the highest resolution currently available in commercial typesetting. Other Macintosh and IBM computers were purchased for various pricing, mailing, and costing functions including an automated pricing and information program for the Copy Centers that was developed this year. A vastly improved color copier from Canon was purchased for the Building 11-004 Copy Center as well as the usual complement of black and white replacement copiers for the Institute copier program and the Copy Centers.

Space is presently being prepared for another copy center in the basement of the newly renovated Stratton Center. It is expected to be in operation in September 1988, 24 hours per day, seven days a week, on a partially self-service basis.

JAMES W. COLEMAN

Housing and Food Services

Housing

Phase one of a comprehensive residence security program was completed this year. Day and night operations were observed in each residence in order to produce a 24-hour security needs analysis. This analysis was then used to guide us in implementing programs to upgrade and secure all exterior doors and windows, all key and locking controls, lighting, and access desk controls in each of our houses. Phase two, which began during the year, includes residents' security education programs, security marketing programs, and plans for comprehensive access desk and night watch controls.

Renovation of the lower level of Ashdown House was substantially completed this year. This space, which will be ready for occupancy at the beginning of the next academic year, will provide quality housing for 29 additional graduate students.

Another graduate housing project initiated this year is the conversion of a building located at 143 Albany Street. This building will be totally renovated to provide housing for 185 married and single graduate students. Our ambitious goal is to complete this project by September of 1989.

An administrative reorganization was implemented to develop a graduate operations program to meet the need for direct leadership action in graduate housing administration. This program works in tandem with the traditional undergraduate program but identifies and initiates plans and proposals to achieve specific objectives for our graduate residents.

During the year, the department completed several alteration and maintenance projects, including a sprinkler system installation and two graduate resident apartments at Baker House; air conditioning equipment at East Campus and New House; window replacement at Random Hall, 500 Memorial Drive, and Ashdown House; rebuilding parapet walls at Senior House and Ashdown; and cable television installation at Baker, McCormick, and New House. A large asbestos removal project at Westgate was completed as well as substantial alterations in conjunction with the installation of the new telephone system early next year.

Food Services

Food service operations in the Stratton Center were greatly curtailed during the entire year due to major renovations. Construction of a new food court and major renovation to Lobdell are on schedule and a September 1988 opening promises to provide several new service options and a wide variety of food choices for the entire MIT community. Despite having this major food service facility operating on such a limited service basis all year, overall food service sales were a solid 96 percent of last year's sales.

A full service seafood restaurant will also be included within the renovated Stratton Center. Networks will be a fresh seafood restaurant offering both full-service dining and take-out service. The restaurant will serve faculty, staff, students, and guests of the Institute.

Cart service was initiated in Lobby 13 as a partial substitute for service in the Student Center this past year. At its peak, 900 members of the Institute community were served there each day. This program was so successful that plans are underway to make it a permanent operation.

An excellent working relationship was established with the Undergraduate Student Association and their Food Service Committee this year. New approaches to issues such as weekend meal service, meal plan minimums, and the establishment of house dining service committees were developed and implemented.

Throughout the year, Food Services catered approximately 1,360 events, including the Johnson Games, Athlon Ball, Special Olympics, Commencement, and Technology Day and Alumni Week.

Personnel

Harmon E. Brammer moved to Physical Plant at mid-year after 15 years as department Director. His contributions to building the strong human and financial resource base which the department enjoys were exceeded only by the goals he set for creating a department attitude fully responsive to meeting MIT student and community needs. Lawrence E. Maguire, Associate Director, became Director in January. August Perry, Manager of Maintenance, retired last July after 17 years at the Institute.

LAWRENCE E. MAGUIRE

Office of Facilities Management Systems

Within the last year, the Office of Facilities Management Systems (OFMS) has developed and strengthened its three major functions. The Office's primary responsibility is the operation and maintenance of MIT's space accounting system, INSITE, and all of the ancillary services necessary to account for MIT's 9 million gross square feet of space. Annual field verification of all space is performed, as well as two major updates to the space inventory file, and a continuing update of MIT's scaled floorplans. Underway is a new major effort to electronically digitize a majority portion of MIT's floorplans; completion is expected early next year. To maintain and update these electronic files, a new position, Architectural CAD Assistant, was filled. This position reports to the Facilities Information Manager who is responsible for maintaining the database, performing annual audits and ad hoc utilization studies, keeping historical records, and providing indirect cost data to the comptroller's study for plant-pool costs.

The second basic OFMS function, the operation of the Consortium, has expanded and incorporated two new features: the addition of a second day to the annual workshop at MIT attended by Consortium members throughout the United States and Canada, and the development of two new training courses for INSITE users. Basic and Advance INSITE training is available to MIT users, as well as to consortium members.

During the year, several new PC systems were released: ANALYST, an electronic spreadsheet displayed as an organizational tree (a hierarchy), and CAD VIEW, a read-only floorplan display system for management information purposes.

The third major area of activity, Facilities Management Education Programs, has seen an unprecedented attendance response both for the annual conference and the semi-annual Course for Senior Executives, which for the first time was offered overseas. In cooperation with the MIT Laboratory of Architecture and Planning, OFMS participated in Symposia for the MIT Industrial Liaison Program and the General Services Administration. The department was also invited to provide Facilities Management Workshops for the Japanese Institute of Architects and the Japanese Facilities Management Association. In addition, the Director gave presentations to Japanese visitors at MIT and has traveled to Japan on several occasions for this purpose. While Institute support activities have grown and intensified, international development has broadened the OFMS outlook.

KREONL. CYROS

Physical Plant Department

The electric utility industry in Massachusetts is in a serious period of instability with inadequate capacity and energy reserves to meet an expanding market. Experts believe that under the best scenario this situation may last for two or three more years. These problems are resulting in wide and unpredictable swings in the price of electricity; a situation which makes energy budgeting at the Institute very difficult. In FY1988, a year of very stable oil and gas prices (prices held within an unusually narrow range of ± 5 percent), our electricity price which has traditionally tracked oil price action closely month to month, experienced swings of 20 percent or more. The result was a significant budget deficit at year's end, demonstrating graphically the importance of energy conservation initiatives to control costs in our energy intensive research and computerized environment.

One Institute response to this problem is participation in the Cambridge Electric Light Company's electricity conservation rebate program. This is a formal retrofit effort which will have a construction price tag of \$3.7 million when completed. The program has now progressed through a complicated ten month survey, design, and contract negotiation process moving toward the start of construction at the end of the year. After the next year of concentrated activity by five separate energy service companies, touching almost every room on campus, new, more efficient electric devices, controls, motors, and lighting equipment will generate energy savings and rebates with a value of over \$1.5 million per year. This is a shared savings program and the Institute's net energy cost reduction for the first three years of the program, the period when the energy firms recover the bulk of their major retrofit investment, will average \$500,000 per year. Beginning in 1993, essentially all of the savings will be applied to budget reductions.

The Institute's other major energy cost control initiative, a cogeneration project which has potential for significant cost containment, continues under study and negotiations with local gas and electricity utility suppliers. It is proving difficult to guarantee feasibility given the current fuel cost and avoided electric cost proposals within the regulatory infrastructure in Massachusetts.

Significant progress was made this year on treatment of the important campus environmental hazards, asbestos and PCB contamination of electrical equipment. The Plant is more than halfway through a phased program for the safe and cost-effective abatement of PCBs in campus electric transformers. It is anticipated that all PCBs will be removed from the campus by 1990. During the spring term, the EPA conducted a surprise audit to test MIT's compliance with PCB rules and regulations on campus and the Institute was found to be in full compliance. In the spring, the first phase of our asbestos survey program, 12 buildings on the East Campus, was completed. A proposed abatement plan for this area is currently under review.

The development of the new Physical Plant management information and financial control system continued. Training of employees in the use of the system started and will continue through the next year as the various modules are completed and come on line. Initial reception of the new system by managers and supervisors is favorable.

Facilities Construction and Renovation

Renovation of the east basement space in Ashdown House to provide efficient updated service facilities and 29 new graduate student beds was completed in June. The new spaces are proving to be a very desirable adjunct to the on-campus graduate housing stock.

Housing resources for graduate students will be further improved by a renovation, now in design, of a classic red brick mill building at 143 Albany Street into a 185 bed graduate student "apartment-type" dormitory. Current projection for occupancy is the fall of 1989.

Design was initiated on renovations and an addition for the Rotch Library which serves the School of Architecture and Planning. The size of the library will be tripled by the addition of a six level section to the easterly elevation of Building 7.

Programming and design were completed in the spring on a project to renovate the Eastman Laboratories Lecture Hall (6-120) to a state-of-the-art audio/visual lecture facility. A fast-track construction effort is underway in order to deliver the rebuilt hall for September activities.

The former TRW/Carr Fastener site on Ames Street was partially converted to interim commercial parking. The remainder of the site is intended for the proposed new Biology Building. Architect selection for this project is currently underway.

During the year, significant space change renovation projects were completed in Buildings E19, NW12, and 24 for the new 5ESS telephone switch; in Building 20 for the Biotechnology Process Engineering Center; and in Building E25 for Brain and Cognitive Sciences. A major rehabilitation of Humanities space in the north wing of Building 14, including air conditioning, was also initiated.

Building Operations

The first module of the new Physical Plant on-line management information and financial control system was put into service in the Plant Operations Center where approximately 120,000 calls about facilities problems and conditions are received annually. This module permits the console operators to replace manual recording of trouble calls with computer logging, thus providing greatly improved operations capability and service to the community.

The Managers of the Central Utility Plant and Mechanical Operations jointly conducted a seminar at which representatives from eight water treatment chemical vendors, a faculty member, a water treatment consultant, and Plant personnel reviewed the various treatment requirements for Physical Plant heating and cooling systems as well as the products available in order to determine the best approach for each type of system. Based on the material presented, a new specification is being prepared which will be used to obtain bids offering the best service at lowest possible price.

Support Services and Building Maintenance

The Grounds Department is continuing with the execution of the campus beautification program which was developed jointly with the Planning Office. Considerable effort was also spent in restoring the campus grounds following the installation of the underground telephone cable system. An automatic irrigation system was installed at the E15-E25 plaza and a similar system is scheduled for Killian Court this summer.

The repointing of the limestone caps of the Buildings 7 and 10 domes was completed. Other major projects were the replacement of the roofs on W59 and N52, the complete repointing of Building 9, and the replacement of expansion joints in the atrium of Building 34. Plant personnel are currently working informally with the Indiana Limestone Institute concerning topical problems associated with acid rain and other airborne pollutants. A major section of the sailing pavillion dock was replaced with one of freestanding design to improve resistance to the impact of river ice. The work included extensive driving of new wood piles.

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. During the year, several major efforts, involving all three aspects of the Office's mission, were initiated.

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 updated and distributed to all faculty, departments, and offices on campus. 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; prototype development of an electronic hypertext-based version of the Factbook is currently underway.

Ongoing efforts of the institutional research staff include development of a computerized system supporting the Provost's Five Year Planning process, continued development of planning database systems, design of a comprehensive capital needs and planning document, and the development of an executive information system. Unlike many departments which require data for their own personnel only, the Planning Office has special information 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.

In light of these needs, the office initiated response to a request for proposals for the New England Regional Computing Program (NERComp). In cooperation with the Budget Office, the Office of Sponsored Programs, and and Information Systems' Architecture and Strategic Technologies group, the Planning Office will be the subject of a case study on the implementation of decision support systems. In addition, the IR group has made presentations for staff and interested people at the Institute, and at the national conferences of the Association for Institutional Research and the Society for College and University Planning on information management issues. Staff have also been participants on several Institute committees, including the Support Staff Working Group and the Administrative Workstation Committee, which is reviewing and recommending microcomputer resources for departmental administrative use.

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.

Other planning efforts included the completion of planning for a new graduate residence at 143 Albany Street and the continuing review of housing site alternatives for students, faculty, and staff; preliminary planning for a proposed computer science laboratory; exploring methods for expanding opportunities for sororities and other independent residences; and design 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 the 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 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

The completion of major elements of the Kendall Square urban renewal project have all had an impact on the Institute's immediate environment. These include the opening of the new hotel, the opening of the relocated Tech Coop, the new Kendall/MIT subway station with an historical time line exhibit designed by Deitmar Winkler, and the redesign of Main Street.

The University Park project on the former Simplex property and Cambridgeport continue 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

A major review of the Institute's Workers' Compensation program was conducted this year, including the possibility of self-insurance and a model program designed specifically for MIT. These suggested changes will provide more internal control resulting in more effective management of insurance claims. Changes in the Workers' Compensation Law have produced additional costs, but a downward trend is establishing itself.

Education and Training

The Medical Department and Clinical Research Center have completed their emergency action plan programs which culminated with fire evacuation drills. These departments also held training sessions in fire awareness and conducted thorough safety inspections of their facilities.

Most departments now have mandated safety training programs. These programs are well attended since laboratory work cannot begin unless this safety training has been completed.

Hazardous Materials

New legislation will require changes in the procedures for disposal of needles/syringes, polychlorinated biphenyls (PCB's), electrical storage batteries, and waste oil. A careful review was conducted concerning the proposed legislation for Source Reduction, Toxic Chemicals and Waste Minimization, as well as the Massachusetts Contingency Plan and Spill Notification Regulations.

Laboratory Safety

Several laboratory safety procedures were developed or expanded throughout the year.

Fire Protection

A considerable amount of time has been spent on the High Rise Sprinkler Program this year and legislative efforts were closely followed. Currently, MIT has approximately 20 high rise buildings. The Institute's general program has been developed but awaits final determination of regulations before implementation can proceed. Housing is the central focus of the program.

Modern fire alarm systems have been installed in Buildings 13, W23, and W33. Improvements to fire alarm systems were made in Technology Square and Endicott House.

Several new fire alarm systems were tested and fire evacuation drills increased significantly. There were less than \$5,000 in fire losses this year.

Safety Audits

A program to clear corridors of obstructions and other hazards was initiated this year. Inappropriate use of corridor spaces has grown in recent years requiring the need for a campus-wide clean-up program.

Several other safety audits were conducted including audits in Buildings W20 and 50, the Medical Department, and the Clinical Research Center.

Second exits were installed in both the Hayden Library and on the first floor of the Alumni Pool in order to comply with the Building Code Compliance Program.

Again this year, campus wide inspections were conducted by Kemper Insurance and the Cambridge Building Department.

JOHN M. FRESINA

VICE PRESIDENT AND TREASURER

INTRODUCTION

The highlight of the year was the formal kickoff of the Campaign for the future held on October 22, 1987 at Walker Memorial. Staff devoted an important part of their efforts to the planning and holding of this event and subsequent regional kickoffs in six locations.

At the same time that the kickoffs were taking place, the staff was also fully engaged in identifying and qualifying prospects. Working with senior officers and key volunteers, significant cultivation and solicitation efforts were also directed at individual prospects. Efforts to raise funds from corporations and foundations were particularly successful and resulted in a meaningful increase in both commitments and gifts received. The total amount received from gifts, grants, and bequests and membership fees in the Industrial Liaison Program reached a new high of \$91.9 million, an increase of 20% over the results of the previous year. Total Campaign gifts and pledges increased by \$141.7 million during the year and the Campaign total was \$314.2 million at fiscal yearend.

The two major activities of the department are divided into Resource Development - Gifts and the Industrial Liaison Program (ILP). The missions of the two organizations came closer together as the ILP staff began to assume more responsibility for Institute relationships with their member companies. This was formalized at yearend and will be fully implemented during the next few years.

Resource Development - Gifts continued to expand its staff as the Campaign got fully underway. Most of the key staff appointments had been made prior to the beginning of the year and there were no changes in those responsible for supervising the staff. The Director of Donor Relations and Campaign Visits resigned in September and these activities were divided between the National Campaign Office and the Office of Major Gifts. During the year, Resource Development - Gifts hired eleven new staff members (nine women), including the replacement of five staff who resigned or were promoted. In addition, three women were promoted from support to staff positions. The new position of Director of Foundation Relations was established, and on July 1, 1988, was filled by Barbara Stowe, formerly Assistant Dean for Development in the School of Humanities and Social Science. Also, John Wilson joined the staff on July 1, 1988 as Assistant Director of Corporate Development, following a two year appointment in the Office of the Vice President for Financial Operations. Nathaniel Mayes, District Director for the Midwest in the National Campaign Office, was promoted in October to Director of Development for the Sloan School of Management. In March, Elizabeth Ogar was hired as Fiscal Officer to work with the Executive Assistant to the Vice President and Treasurer on department administration. New staff hires, transfers to and promotions within Resource Development - Gifts during FY88 and at the beginning of FY89 included two minorities and thirteen women. Effective in FY89, the Director of Development for the School of Humanities and Social Science will be a part of Resource Development rather than the School, and is included in the 6 open staff positions at July 1, 1988. Every effort continues to be made to identify qualified minority and women candidates to fill all open positions.

PRIVATE SUPPORT

Private support for 1987-88 totaled \$91.9 million, including the following: \$83.7 million in gifts, grants, and bequests, and \$8.2 million in support through membership in the Industrial Liaison Program. The total compares with \$76.4 million in 1987, \$62.8 million in 1986, \$68.5 million in 1985, and \$55.7 million in 1984. Gifts-in-kind for the past year (principally gifts of equipment) were valued at \$5.1 million.

Sources of gifts for fiscal year 1988 were: alumni, \$29.7 million; non-alumni friends, \$3.5 million; corporations, corporate foundations, and trade associations, \$29.9 million; foundations and charitable trusts, \$19.8 million; and others, \$0.8 million. Included in the totals for alumni and friends are gifts of \$1.3 million made to the Rogers, Maclaurin, and Compton Pooled Income Funds. The total fee income of \$8.2 million for corporate liaison programs increased 1% from the previous year.

Donors designated expendable and endowed funds as follows: unrestricted, \$20.9 million; departments, \$28.6 million; faculty salaries, \$11.2 million; graduate student aid, \$5.6 million; undergraduate student aid, \$4.7 million; building construction funds, \$3.7 million; and other funds, \$9 million.

When the Campaign was formally announced in October 1987, the Nucleus Fund totaled \$210.9 million. Since then \$103.3 million in gifts and pledges has been raised, bringing the Campaign total to \$314.2 million. This total includes gifts and pledges for endowment and unrestricted purposes since July 1, 1984, and for all Institute purposes since January 1, 1986.

OFFICE OF MAJOR GIFTS

The Office of Major Gifts began operation under the direction of H. E. (George) Ramonat in November 1986 with the clearly stated goal of managing individual prospects with the potential to contribute \$500,000 or more to MIT over a five year period. The Office is fully operational, and in January of 1987 began its proactive approach to the prospect pool. As of June 30, 1988, 68 face-to-face solicitations were made, resulting in gifts and pledges of \$38.0 million from prospects rated at the major gift level. Using the correct assumption that many MIT prospects need cultivation prior to any face-to-face solicitation, 92 personal cultivation calls were also made during this period. In addition, non-kickoff related cultivational events hosted by prominent and visible alumni featuring distinguished MIT faculty and administrators as speakers were held.

Major Gifts Officers are Lucy Miller and Lee-Ann Day. Ms. Miller has responsibilities in the Middle Atlantic States, manages the principal gifts program, and supports the student aid needs for the Campaign. Principal gifts is a new function that provides focused efforts toward servicing our largest individual donors. Ms. Day concentrates her efforts on prospect management in New York Metro, Boston, Florida, Atlanta, Europe, Canada, and the Western Hemisphere.

In addition to his responsibilities as Director, George Ramonat manages the balance of the prospects in the U.S. and the Pacific Basin. He also directed the efforts to support the cultivation and solicitation efforts of the Chairman, President and the Corporation Campaign Committee chaired by Carl Mueller.

Major Gifts research efforts are managed by Assistant Director Margaret Gutowski, who coordinates the work of three research analysts. Collectively they produced or held the following in the last 18 months:

Solicitation Plans	68
Cultivation Plans	92
Information Requests	193
Strategy Sessions	89
Major Gifts Qualifications	30

Julie Eastman joined the office as Assistant to the Director for Donor Relations. Major Gifts, along with Campaign Systems, Development Services, the Alumni Association, and the Recording Secretary's office, formed a working group to document the gift entry, gift acknowledgment, and appreciation process. This was completed in May of 1988. The Chairman's Office joined the President's Office in writing letters of appreciation for gifts and pledges of \$1,000 and higher from individuals, corporations, and foundations.

Finally, the office initiated 22 group cultivation events in Florida, New York, Dallas, San Francisco, Silicon Valley, Houston, Milwaukee, Chicago, Paris, Geneva, and Hong Kong with 260 alumni and friends attending.

NATIONAL CAMPAIGN OFFICE

The year began with the recruitment of volunteer leadership well underway. Activity this year focused on expanding the size of the volunteer organization throughout the country by enlisting alumni volunteer solicitors for each of the 25 active Campaign committees. D. Reid Weedon, Jr. '41, Chairman of the National Campaign Committee, worked closely with the Director of Campaign Operations, Henry Barg, '73, the seven District Directors and 43 area chairmen and vice chairmen, to recruit a total of 157 alumni volunteers who also have the responsibility to cultivate and solicit prospects capable of making Campaign gifts in the range of \$50,000 to \$500,000. Significant progress in training the volunteers and assigning prospects to them was made in the key markets of Boston, New York, Silicon Valley, Washington, D.C., Philadelphia, and Los Angeles. Prospects were assigned based upon their philanthropic potential, inclination toward MIT, volunteer's knowledge of the prospect, reunion cycle, and giving history. Seven Campaign kickoff events began the cultivation process for the respective volunteer committees. Additional kickoffs, smaller off-campus cultivational functions, and campus visits are planned to build upon the momentum generated by this past year's Campaign efforts.

New District Directors hired this year are Sarah M. Carothers, Alfred R. Doig, Jr. '76, and Diane M. Goldin. The assignments for the field staff of the National Campaign Office went through a few changes due to additions to staff, a transfer, and a replacement. The major geographic responsibilities of each District Director at year's end are as follows:

Sarah M. Carothers	Chicago; Dallas; Houston; Cleveland; Detroit; Pittsburgh; other Midwest
Alfred R. Doig, Jr.	New York City; New Jersey; Fairfield/Westchester
Diane Goldin	Florida; Connecticut; New Hampshire; Atlanta; other Southeast; other New England
Marilyn Kuhar	Boston; other New England
John Larson 80 MG	Silicon Valley; Boston (high tech)
Marie O'Connor	Washington, D.C.; Philadelphia; Los Angeles; San Francisco; Baltimore; Wilmington; Seattle; other Southern California
James Phinney	New York City; Long Island

Sustaining Fellows and Special Events

In July, Cassandra Page joined the National Campaign Office to manage Sustaining Fellows and Special Events. To assist with the Sustaining Fellows Program and the numerous cultivation events, Meredith Thomas was hired in April as Assistant Manager.

The Sustaining Fellows Program underwent minor revisions to clarify recognition ambiguities and to make the program more responsive to its donors. For example, any gift of \$3,000 to \$24,999, regardless of Institute purpose, now qualifies a donor as an Annual Sustaining Fellow. Lifetime gifts totaling \$25,000 or more qualify for life membership. Additionally, participation as an Annual Sustaining Fellow is now based on the Institute's fiscal year and annual donors who give between July 1 and June 30 are recognized as Annual Sustaining Fellows for that fiscal year. Formerly the membership was based on a 15-month reminder schedule. All Sustaining Fellow unrestricted gifts up to \$3,000 per year are monitored and that total is provided to the President at the end of the fiscal year for designation. A reorganization of the Sustaining Fellows database was undertaken to streamline the record keeping.

Letters and phone calls from Sustaining Fellows indicate an enthusiasm for the program and their gifts demonstrate a strong interest in supporting the Institute. Many Sustaining Fellows were invited to Campaign events held during 1987-88 and were included among the total of 732 who attended the Cambridge kickoff on October 22 and the New York kickoff on December 3.

Five additional campaign-related events were held in 1988. A total of 469 alumni and friends attended the following kickoffs:

Longwood Gardens, Pennsylvania - April 6, 1988
Cocktail reception and dinner
Speaker: Paul Gray

Wilmington, Delaware - April 19, 1988
Cocktail reception at du Pont home
Hosts: Barbara and Irene du Pont
Speaker: Paul Gray

Washington, D.C. - April 28, 1988
Cocktail reception and dinner
Speakers: George Shultz, Paul Gray

Baltimore, Maryland - May 11, 1988
Cocktail reception and dinner at Wagley home
Hosts: Mary Frances and Philip Wagley
Speaker: Paul Gray

Los Angeles, California - May 15, 1988
Symposium, cocktail reception, dinner
Host: Hughes Aircraft Company
Speakers: John Deutch, David Baltimore
Robert Birgeneau, Robert Solow

Guests' genuine appreciation and enthusiasm for the kickoffs have been encouraging and plans are in progress for 1988-89 events which include kickoffs in San Francisco, Cleveland, Atlanta, Dallas, Silicon Valley, Chicago and Detroit, as well as additional cultivational affairs in New York, Boston, and Florida.

Campus Visits

At the beginning of its second year of operation, the Campus Visits program was moved from the Office of Donor Relations and Campus Visits to the National Campaign Office. Cassandra Page, Manager of Sustaining Fellows and Special Events, also served as Campus Visits Coordinator, until the hiring of Estelle Cashman who assumed that position in December 1987.

Six campus visits were held during the year, three in the fall and three in the spring, which brought 148 alumni and friends of MIT back to campus as guests of the Institute. The format for each 36-hour visit was similar: a reception and dinner at the MIT Museum Thursday evening; a full day of informational programs on Friday, dinner that evening at the President's House hosted by Dr. and Mrs. Gray; and a wrap-up breakfast Saturday morning.

Two of the campus visits (one in the fall and one in the spring) were of a general nature, focusing on a wide variety of Institute activities. Each visit included programs and laboratory tours which allowed for lively interaction between campus visitors, students and faculty members.

The School of Science and the Alfred P. Sloan School of Management, respectively, hosted campus visits which not only highlighted programs, faculty and students from these schools but also gave visitors the opportunity to hear what was happening elsewhere on campus.

For the first time, two of the campus visits centered around special interest groups: one for members of the fortieth reunion class of 1948, and another for MIT alumni and friends who are entrepreneurs in high technology fields. While these visitors had similar interests and their visits were designed to include subject matter of particular concern to each group, the content of the programs introduced a wide range of MIT activities and people. Planning is now underway for another six visits during the 1988-89 academic year.

OFFICE OF CAMPAIGN SYSTEMS

The Office of Campaign Systems completed its first full year of operation under the direction of Shelley Brown, continuing to provide support to the Campaign through prospect research and information management. The Office prepares research reports for the use of the National Campaign Office and their volunteers; the Office of Corporate Development; the ILP; and the Campus Visits, Sustaining Fellows, and Reunion Giving Programs. This year, more than one thousand reports were completed on prospective donors to the Campaign.

Campaign Systems staff also are responsible for the Campaign's prospect identification efforts and for the development and administration of Campaign management reports, including both prospect tracking and Campaign statistics. Working with the Cadence Group and representatives from the Major Gifts Office and Development Information Management Services, the Office successfully completed the creation of a Prospect Management System. A variety of reports showing Campaign giving totals also were completed this year, with the support of the Office of the Recording Secretary and Administrative Systems Development.

Several key staff changes took place this year. Lisa Peterson joined the office as Assistant Director, responsible for prospect qualification and identification efforts. She also manages research support to the Office of Corporate Development and other clients and the administration of the prospect tracking system. Elizabeth Garvin, who has served as Assistant Director since the Office was organized in February 1987, continues to head the research group supporting the National Campaign Office, and to oversee the Development Office files and reference library. Mary Gulino was promoted to the staff position of Coordinator for Production Systems Support, responsible for the Macintosh network serving Major Gifts, Development Services, and Campaign Systems. She also provides production support to the Campus Visits and Special Events programs.

During the year the office of Development Information Management Services (DIMS) was transferred to the supervision of Shelley Brown. As a separate unit within the Office of Campaign Systems, it provides programming support to all users within Resource Development, and oversees equipment acquisition, training, and support. This year, Gregory Whall was promoted to the position of Manager of DIMS, and James Polk joined the staff as Analyst Programmer.

OFFICE OF DEVELOPMENT SERVICES

The Office of Development Services was established two years ago to address the needs of the five schools and the Office of the Provost for fundraising support services and liaison to the Resource Development organization. Jack Oldham, the director, chairs the monthly meetings of the school development officers, coordinates the allocation of resources, and manages the research and support activities provided. The assistant directors serve as direct links to the school development officers and to the provost, providing prospect identification and research,

proposal writing, project management, clearances, reports and stewardship plans as needed. They, in turn, draw upon a pool of research analysts who build prospect lists for faculty projects and provide background information for solicitation and cultivational visits to individuals, corporations and foundations.

The year 1987-88 was extremely productive with respect to school-based fundraising, which at M.I.T. tends to be project-driven rather than prospect-driven. Atop the list of successful projects was the \$30 million in corporate commitments (including over \$15 million in endowment) raised by Deans Gerald Wilson and Lester Thurow, Professors Kent Bowen and Thomas Magnanti, Assistant Dean Eric Johnson of the School of Engineering, and their colleagues within the "Leaders for Manufacturing" program, a joint effort of the faculty in the School of Engineering and the Sloan School of Management.

The staff also assisted efforts to bring support in the form of grants, rather than gifts. A major accomplishment involved concerted efforts by the Provost, the President, the Dean of Science and the faculty of the Biology Department, culminating in an agreement with the Howard Hughes Medical Institute. This agreement provides for \$15 million toward construction costs and also substantial faculty research support to establish a Hughes research center within the proposed \$60 million new Science Complex. John Jacoby, Assistant Director of Development Services and Judy Gooch, Director of Development for the School of Science, provided essential staff support and coordination throughout the negotiations.

Within the School of Humanities and Social Science, Dean Ann Friedlaender and Assistant Dean Barbara Stowe, with the support of Lisa Hiley, Assistant Director of Development Services, had another excellent year, securing major foundation grants in support of curriculum development and for teaching and research programs in arms control and international security.

In the School of Engineering, Director of Development Rodger Crowe and Nancye Mims, Assistant Director of Development Services, teamed up with the faculty of the Chemical Engineering Practice School to build that program's endowment, which is now in excess of \$5 million. Ms. Mims, working closely with Dean Johnson and Professor Douglas Carmichael, was also responsible for the most successful year in the thirteen year history of the MITES program (Minority Introduction to Engineering and Science).

While Dean Thurow and the Sloan School faculty concentrated upon revising that school's programs to emphasize the international and technological dimensions of management education, Director of Development Nat Mayes and Mary Leen, Assistant Director of Development Services, were identifying and researching major individual and corporate prospects to be approached during the coming year. A small number of international corporations pledged support for professorships and fellowships, and additional negotiations are in progress.

In the School of Architecture and Planning, the renovation of the Rotch Library has received administrative approval to proceed and the search for a naming grant has intensified. Other priorities, reported by Assistant Dean Deborah Cohen, include fellowship support, faculty chairs, research funds, and the renovation of the Level One Studios. Newly established chairs include the Norman B. '38 and Muriel Leventhal Professorship in City Building and the Edward H. '62 and Joyce Linde Assistant Professorship in Urban Development.

There were two changes among the administrative staff in the fall. Janice Thompson was promoted to assistant to the director, succeeding Phyllis Gallant, who retired after twelve years of service. Mary Leen, previously acting director of prospect research within the Boston College capital campaign, was named assistant director with responsibilities for the Sloan School and the School of Architecture and Planning. At year's end, searches were under way for two additional assistant directors, and two new research assistants were hired to start in July.

CORPORATE DEVELOPMENT

The Office of Corporate Development, directed by Frederick Gross, continued to track 150 major corporate prospects and report on them on a quarterly basis. Direct support was provided on the submission of 12 proposals for major gifts from corporations (4 of which have already been successful).

A corporate strategy group made up of staff from administrative offices, Resource Development, and the schools met biweekly to discuss and develop strategy for approaches to specific corporations and industry groups by their interests (e.g. Europe, Japan, and Korea). These meetings have stimulated some cooperative efforts.

Three major internal projects were also initiated: a study of recruitment and career paths of our alumni in industry; a tracking and stewardship planning system for corporate and foundation gifts; and a brochure for corporate solicitations. All three projects are expected to be completed and in use prior to the end of 1988.

A new corporate development program to cultivate and solicit support from defined corporate philanthropy programs is being developed. Efforts are also being initiated to cultivate and solicit for endowed fellowships from corporations.

OFFICE OF FOUNDATIONS AND CORPORATIONS

Vincent DeBaun, Director, assisted in raising funds from specific foundations and corporations and also provided advice to school development officers and others who raise funds from these sources.

Robert Hagopian, Director, National Business Committee, continued to develop new relations between MIT and both corporations and government organizations. He also developed important relationships with alumni and friends and assisted other staff in this process.

CORPORATION DEVELOPMENT COMMITTEE

The annual meeting of the Corporation Development Committee (CDC) with Chairman David Saxon presiding was held on October 23, 1987, in conjunction with the launching of MIT's \$550 Million Campaign for the future. This meeting, to which spouses were invited, was attended by 74 members, plus special guests and members of the Institute staff. It marked the twenty-third year of operation for this group. The meeting focused on several aspects of the Campaign, namely the volunteer organizations, campaign priorities and campaign strategies for volunteers. A highlight of the meeting were the remarks made by Cecil Green '23, Honorary Campaign Chairman. He drew on his own experiences to illustrate the need for donor cultivation and involvement.

The recipient of the Marshall B. Dalton '17 Award was Karl R. Van Tassel '25, who was cited for "his more than half century as an alumni leader of MIT."

With deep regret the CDC noted the death of one of its members, William B. Bergen '37.

COMMUNICATIONS

The Campaign dominated the activities of the office, under the direction of Elizabeth Harding. Communications coordinated the design of all the kickoff invitations and special materials such as programs, a campaign paperweight, and an abbreviated version of the campaign case that was used as a dinner program in Cambridge and subsequent kickoffs. A multi-image presentation, "Thinking About the Future," was completed by Jonathan Spring '79, a principal of Image Presentations. The show, produced in slide and video formats, won a CASE (The Council for the Advancement and Support of Education) gold medal in the spring of 1988.

Two other major events were the introduction of a campaign newsletter, Spectrum, and the release of the Campaign Casebook. Spectrum, which covers news of the Campaign and features people and special programs at MIT, will be mailed within the Institute and to approximately 10,000 alumni and friends. The Casebook, designed by Carr Associates, will be used by volunteers and MIT staff to solicit substantive gifts throughout the campaign.

Other materials completed included: MIT Facts 1988; a series of departmental profiles for the School of Engineering; a stylebook guiding the use of the logo in campaign materials; a poster, Research Firsts; and a scholarship brochure, The Kevin Lynch Award. In addition, a number of proposals were sent to individuals, corporations, and foundations. Work commenced on several brochures to be completed by the fall of 1988. These included: MIT and Industry; Named Giving Opportunities; Fellowships at MIT; and the Center for Cancer Research at MIT.

Early in the fiscal year, Theresa Pease joined the staff as Associate Director of Communications and Editor of Spectrum. Sarah Abrams resigned to assume a communications management position at another university.

INDUSTRIAL LIAISON PROGRAM

MIT has traditionally been known and emulated for its leadership in building and maintaining excellent relations with the corporate community. In its 40 years of existence, the Industrial Liaison Program (ILP) has helped to create that tradition, and has become a sophisticated service organization meeting the needs of both the MIT faculty and the corporations which form its membership.

At this juncture, though, the needs of both the Institute and the corporate community have changed, and the ILP must change as well. Corporations increasingly seek involvement with specific activities, and will provide meaningful research support and restricted gifts to such activities. Faculty are increasingly looking for assistance to encourage this process. The Program wishes to acknowledge these shifts, and put its full resources into efforts which will assure resounding success in raising research funds as well as unrestricted income.

The central theme of the year for the ILP was a redirection of effort to obtain greater support from corporations for MIT's academic priorities in general and for MIT's Campaign for the future in particular. In response to a request from the Vice President and Treasurer, a new mission was prepared and was approved by President Gray on July 1, 1988. The Liaison Program Faculty Committee has met throughout the year to guide this process and gave its approval on May 4,

1988. The entire staff of the Program met at Endicott house on April 8, 1988 with representatives of member companies: Mr. Rudy Schlais of General Motors, Dr. Peter Bell of Norton, Dr. Peter Cukor of GTE, Mr. Allan Jones of Digital and Mr. John Blair of Raytheon, to discuss the statement. The final proposal was completed on April 12, 1988 by Thomas Moebus, Associate Director. The highlights follow:

Mission of the Industrial Liaison Program

The mission of the Liaison Program is to create and strengthen mutually beneficial relationships between MIT and other corporations.

1) Role with MIT Faculty

The Liaison Program will assist Faculty to develop useful contacts with industry, including those which will lead to both restricted and unrestricted funds. The Program will strongly support the educational and research priorities of MIT as they relate to corporate involvement.

2) Role with Corporations

The Liaison Program will actively seek to increase the involvement of corporations as partners with the Institute. The Program will maintain a fee-for-service membership, but will emphasize the cultivation and stewardship of major corporate sponsors of MIT, in collaboration with the Faculty and Administration of the Institute.

3) Role within Resource Development

The Liaison Program will coordinate extensively with Senior Institute Officers, Faculty, and other Administrative Staff to accomplish the broader development goals of the Institute.

4) Staffing

The Liaison Program will continue to recruit technically trained and industrially experienced individuals, capable of representing MIT in all ways consistent with this expanded mission of the program.

5) Implementation

Implementation of this plan will occur gradually, perhaps encompassing 50 member companies per year over a period of several years, and a growing network of faculty.

During the past year the ILP has begun to meet with the deans and department, laboratory and center heads to explore ways to more closely support their plans and priorities. During the next months each one will be briefed about the new mission and its implications. A special meeting is also planned for all member company Policy and Working contacts to be held on October 20-21, 1988.

Other highlights of the year included the implementation of a policy on industrial collegia of the Research Laboratory of Electronics and the Biotechnology Process Engineering Center. Additional proposals will be sought from faculty groups to expand activities under the guidance of the new policy. The ILP has also greatly expanded the seminar series initiated last year.

The Program produced a cash income in excess of \$8.2 million this year compared with \$8.0 million last year. Fully accounting for all membership commitments, including affiliate memberships, would result in a figure in excess of \$9.3 million for this fiscal year compared with \$8.6 million in the past year.

With Texaco's membership check presented on March 1 the Liaison Program's cumulative revenues since its founding in 1948 topped \$100 million. Mr. Richard R. Dickenson, Vice President of Technology at Texaco, was assisted by Dr. John T. Nolan, Director, Texaco's Research and Environmental Affairs Laboratory, in presenting the check to President Gray. Texaco was one of the first five companies to join the Liaison Program when it was founded in 1948, and coincidentally gave the Program the first membership check it received in that year. Dr. Gray spoke of the manifold contributions made by the Program to MIT which he said extend far beyond the significance of the fees paid for its services. Dr. Gray paid special tribute to the memory of former President James R. Killian and his vision in founding the Liaison Program. The coming academic year will be marked by several special symposia to celebrate the 40th anniversary of the Program's founding.

Personnel changes during the year included the promotion of Cynthia Bloomquist to Associate Director and Coordinator for the Program's marketing activities. Other promotions included: Dr. John Leech to Group Leader for the Materials and Manufacturing Group; Anita Horton to Senior Liaison Officer and Group Leader for the Services Group; Diana Garcia-Martinez, Laura Robinson, Marie-Teresa Vander Sande and Sandra Gay Yulke to Senior Liaison Officers; Maria Clara Suva Martin to administrative staff as Conference Coordinator; Junco Norton to Administrative Officer II.

The following resignations occurred during this past year: Gary DesGroseilliers, Lucie Juneau, Susan Lee, Kevin Lonnie, Dr. W. Larry Ritchie, Laura Robinson, Marie-Teresa Vander Sande.

William H. Ramsey was promoted to the position of Executive Director, Engineering Special Programs in the School of Engineering.

The following new officers were appointed: Joseph Baclawski, Dr. Kenneth Goldman, Karl Koster, Dr. Anthony Turano, David Verrill, and Randall Wright.

GLENN P. STREHLE

ALUMNI ASSOCIATION

This has been a year marked by great change. The Association, through its Presidents Committee, instituted a comprehensive review of the organization and role of the Association staff. This has resulted in a major reorganization of the professional staff along market lines. This new organization was announced late in the academic year and takes effect during the upcoming year. The Alumni Fund had its most successful year as measured by the number of donors making contributions. We implemented a new financial control system this year and were able to make use of the flexibility of this new system to effect very tight management control over our financial performance. October saw the beginning of the most ambitious Capital Campaign in MIT's history...the Campaign for the future. Several hundred alumni and guests joined in celebrating the beginning of this most ambitious effort which will reach out to all alumni for support. We closed the year at a very successful Technology Day at which we shared in the celebration of the Centennial of the Materials Science and Engineering Department. At lunch that day two classes announced record-breaking gifts. The Class of 1963 became the first 25th reunion in history to raise in excess of \$3 million and the Class of 1948 more than doubled the record for 40th reunion gifts with a gift of more than \$6 million!

The Association this year was ably led by Raymond S. Stata '57, whose wisdom and leadership enabled us to achieve much more than we dreamed possible in a single year. The Alumni Fund was chaired for a second year by Harris Weinstein '56, who led it to new heights of achievement and success. Key class leaders within the Class of 1938 included Donald P. Severence, G. Edwin Hadley, David Wadleigh and Norman Leventhal, all of whom led and shaped the 50th reunion and reunion gift activity. Within the Class of 1948 that record-setting pace was led by Denman K. McNear, ably aided by George Clifford, S. Martin Billett and countless others. The Class of 1963 was chaired by L. Robert Johnson as head of the gift committee and John T. Lynch as head of the reunion committee. Each of these volunteer committees was superbly supported by an exceptional effort by the staff and are examples of the rare combination of hard-working volunteers and staff achieving the kind of first-rate results we aim for.

The future continues to be bright and a source of challenge. Support by the alumni continues to strengthen MIT as the Institute has strengthened each of us.

Alumni Relations

The National Alumni Conference for 1988 was combined with the Kickoff for the Campaign for the future. It began on Friday, October 23 with a buffet lunch for all alumni at the Cambridge Marriott Hotel, and continued in the afternoon with a series of 9 seminars by key faculty members entitled, "What in the World is Going On?" Among subjects presented were: Chemistry: Molecules that Matter - Professor Mark. S. Wrighton; Changing Patterns of Research and Development in Japan - Professor D. Eleanor Westney; Organizational Structure and Artificial Intelligence - Professor Thomas W. Malone; and The Superconductor Revolution - Professor David A. Rudman.

Friday evening featured a reception and dinner for over 400 people at the duPont Gymnasium, and this served as the actual Campaign Kickoff event. We had the usual NAC events including the Young Alumni breakfast, the Alumni Association's President's Report by Raymond Stata '57, and the Alumni Fund Board report by Chairman Harris Weinstein '56. The NAC Awards Luncheon took place at Walker Memorial and in the afternoon the Educational Council workshop featured the new admissions process. A variety of sporting events and tours were available to alumni in the afternoon.

The weekend concluded with the traditional reception at the President's House and the added feature of an MIT Symphony Orchestra concert featuring guest soloist Carlos Prieto '59.

Technology Day, June 3, 1988, focused on the Materials Science and Engineering Centennial. Professor Merton F. Flemings '51, Head of the Department of Materials Science and Engineering, was the moderator. Speakers were: Morris Tannenbaum, Executive Vice President, AT&T Corporation, Lester Thurow, Dean of the Sloan School of Management, Richard P. Simmons '53, Chairman and Chief Executive Officer of Allegheny Ludlum Corporation, Richard F. Polich ML '65, President of Tallix Art Foundry, and Morris Cohen '33, Institute Professor Emeritus, Department of Materials Science and Engineering.

Reunion programs again brought over 1200 alumni and guests back to MIT. The usual 4 days were preceded by 2 days of the 100th anniversary of the Department of Materials Science and Engineering. Special events were held for returning members of this Department which numbered between 150 and 175. Alumni representing fifteen reunion classes from 1913-1983 were present. Activities took place on campus and at such special locations as the John F. Kennedy Library, Thompson's Island, and the Computer Museum. The traditional Boston Pops Night was a success with record attendance that included MIT staff members.

The Boston Seminar Series had its 6 lectures under the title of Technology and Policy: Dealing with the Consequence of Discovery. Guest speakers included Dr. Richard deNeufville '60, Chairman, Program in Technology and Policy; Honorable John H. Sununu '61, Governor of New Hampshire; Dr. Joseph Weizenbaum, Professor Electrical Engineering and Computer Science; Dr. Phillip A. Sharp, Director, Center for Cancer Research; Dr. Jack Ruina, Director, Defense and Arms Control Studies Program; and, Edward O. Vetter '42, Chairman, Texas Department of Commerce.

AMITA (Association of MIT Alumnae) - The highlight with this group's year was a workshop on the weekend of April 8 and 9. It was co-sponsored with the Society of Women Engineers and over 250 attended. The series had the overall title of "Shades of Gray - Ethics in the Work Place." All events were held in the Bush Room. There were seventeen workshops divided among Professional Skills, Personal Issues, and Ethical Concerns. The keynote speaker was Carolyn Whitbeck, Research Scholar for Technology and Policy Department, and the panel discussion was also held featuring well-known women in publishing, computing, government and higher education. This event was one of the most successful in the history of the AMITA organization.

BAMIT (Black Alumni of MIT) continued to publish its newsletter 4 times a year. The main event for 1988 was a reception for outgoing seniors.

Bronze Beaver Awards: Donald J. Atwood, Jr., Class of 1948; Horatio L. Bond, Class of 1923; Allan S. Bufferd, Class of 1958; and Richard A. Jacobs, Class of 1956.

The Harold E. Lobdell, Class of 1917 Distinguished Service Awards: Yee Wah Chin, Class of 1974; Aaron Kleiner, Class of 1969; Donald Moore, Class of 1924; William E. Murray, Jr., Class of 1967; W. M. Kimberly Roddis, Class of 1977; Robert N. Schulte, Class of 1971; Gwendolyn M. Wise, Class of 1981.

The George B. Morgan '20 Awards: Marshall Baker, Class of 1948; Terrence Chatwin, Class of 1963; John Flynn, Class of 1950; James Levitan, Class of 1945; and Edward Stevens, Class of 1948.

Presidential Citation Awards: MIT Club of Rochester (for sustained excellence); MIT Class of 1948 40th Reunion Gift Committee; MIT Club of the Delaware Valley; MIT Club of Washington, DC (for a public service program); MIT Enterprise Forum of the Northwest - Technology II Conference; CALTECH/MIT Enterprise Forum.

Honorary Membership in the Alumni Association: Michael Egirous; John H. Murphy.

Henry B. Kane '24 Awards: L. Robert Johnson, Class of 1963; Leon M. Kaatz, Class of 1964, Harris Weinstein, Class of 1956.

The National Selection Committee made the following selections for terms starting July 1, 1988:

Elected to the MIT Corporation: Margaret Coleman Haas '50, H. duBose Montgomery '71, Robert A. Muh '59.

Elected President of the Alumni Association: Emily V. "Paddy" Wade '45.

Elected Vice Presidents of the Alumni Association: Harris Weinstein '56, Emily L. Wick '51.

Elected Directors of the Alumni Association: Karen Mathiesen '71, Ernest M. Cohen '64, William C. Morris '60, Hubert E. Knipmeyer '51.

Alumni Fund

The Alumni Fund, under the leadership of Harris Weinstein, Class of 1956, achieved excellent results in this year which saw the launch of MIT's **Campaign for the future**, a 5 year, \$550 million undertaking. Reporting contributions in the amount of \$12.4 million from 28,800 alumni, the Fund achieved the second highest total ever in dollars, while alumni participation increased sharply to a new record level.

Along with most charitable organizations, the Alumni Fund suffered from the effects of the stock market "crash" in October which resulted in a substantive drop off in the number of gifts of appreciated securities in the month of December. Despite this setback, the Fund did very well in the period from January to June. Further, after several years of flat performance in the total number of contributions to the Alumni Fund, this year saw a "net" increase of 1000 alumni donors, thus exceeding the year's goal of 28,000 alumni participants by a wide margin.

At the annual meeting of the Corporation Development Committee in October, Harris Weinstein reported that the Fund has three goals for the **Campaign for the future**. One is to raise \$100 million. The second is to report a \$20 million Alumni Fund by the campaign end. The third is to raise the number of alumni contributing from roughly 28,000 to 30,000 annually and raise the total Fund median gift from \$50 to \$100. As of June 30, the Fund has raised \$42 million of its \$100 million goal in cash receipts with an additional \$10 million received in pledges.

The Major Reunion Gift Program has had another successful year. The 25th, 40th and 50th Reunion classes presented to the Institute on Technology Day gifts totalling nearly \$14 million. The 50th Reunion Class of 1938 raised \$4,127,610 which included over \$1,000,000 for student aid. Also announced by the Class of 1938 was \$3,394,000 in future gifts to MIT. The Class of 1948 more than doubled the 40th reunion gift record, with gifts and pledges of \$6,615,544. Of this total nearly \$850,000 has been designated to establish a class professorship and class scholarships. The Class of 1963 raised \$3,220,390, setting a new 25th reunion gift record for the third consecutive year. The Class of 1963 Scholarship fund has been established with gifts of \$299,000. These campaigns include all gifts and pledges made in the five years prior to the reunion;

pledges are payable over the five years following the reunion.

Also announced on Technology Day were gifts from the 60th and 65th reunion classes. The Class of 1928 presented a 60th reunion gift of \$1,269,000 and the Class of 1923 presented the largest reunion gift ever - \$23 million.

New this year was the Alumni Fund Visit Program, the successor to the Personal Solicitation Program. The AFVP was established as a major part of the Alumni Fund's role in the Campaign for the future. 42 volunteers in Boston, Northern New Jersey, and Rochester, NY contacted 180 fellow alumni to seek five-year pledges of \$5,000. \$490,393 was raised from 119 alumni, with an average gift increase of 58%.

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 17 cities throughout the country. A total of 928 student and alumni volunteers worked together to reach over 15,300 alumni. Of those contacted, 77% made pledges totalling over \$849,000, breaking last year's record.

The Young Alumni Program had a very successful year. Over 750 first-time gifts were received from the five youngest classes, a total of 158 over last year. Alumni from the classes of 1982, and 1984-87 gave of their time to serve as Associate Agents, calling from their homes to solicit gifts from classmates. As a result of their calls, 138 donors, many of them first-time givers gave \$4613. Based on an expanded program, this was an increase of 24 donors and \$1,088 over last year's Associate Agents solicitations. In addition, the Class of 1983 on the occasion of its fifth reunion, raised \$26,335 as a gift--an excellent showing for a fifth reunion class. The Class of 1978 presented a generous tenth reunion gift of \$56,332, with \$27,942 designated to its class project, the Class of 1978 Student Aid Fund. The Student Aid Fund is now endowed at \$117,272 and has funded four scholars. During Fund Year 88, the second year of the 15th Reunion Gift program, the Class of 1973 raised \$63,755. Of the amount raised 49% was designated for the class' project, the Class of 1973 Student Aid Fund. Over 49% of the class participated by making gifts during this one year campaign.

The graduating Class of 1988 presented the Institute with funds to start a "Class of 1988 Scholarship Fund", and announced the four-year pledge total. Some 282 seniors contributed a total of \$6,949 to the Class of 1988 gift which was generously supplemented by a challenge fund from the 50th Reunion Class of 1938. One hundred ninety-one students pledged a total of \$17,836 to the Alumni/ae Fund over a four-year period.

The Graduate Alumni Program, in spite of a mid-year staff vacancy, finished a respectable year, with the total graduate alumni participation at 31%. 416 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, and five graduate telethons were held (four individual departments, in addition to an aggregate effort for graduate housing). There were several successful relations projects, including the completion of the first annual Physics newsletter, continuation of newsletters in seven other departments, celebrations of the Ashdown House 50th Anniversary and the Materials Science Centennial, and formation of a graduate student group to develop graduate alumni events.

This year was significant for the staff of the Alumni Fund. There were several additions to both the administrative and support staff in order to execute the Fund's Campaign plans. Further, in a major change, the staff of the Fund was brought together in a newly renovated space.

During the year, the staff was augmented by the following additions: Susan Anderson, William Downes and Leslie Wolff in the positions of Area Directors, Alumni Fund; Jennifer Archibald was appointed as Graduate Program Director; and Barbara Peterson was promoted to Student Program Manager. Two individuals resigned from the staff: Nelson Armstrong and Nancy Hack.

Finally, one cannot fail to acknowledge the work of thousands of alumni/ae and student volunteers who each year offer their time and talents in support of the Institute. It is their leadership and energy that make the Alumni Fund a continuing success story.

Technology Review

Though the major editorial awards for which Technology Review competed successfully in some previous years eluded us in 1987-88, the magazine's marketplace performance was significantly better than in recent years. Both the response to our direct mail selling and the magazine's acceptance by those ordering trial subscriptions were higher than ever before, with the result that we were able to cover rising costs of printing and--especially--paper while reducing our net cost to the Alumni Association. The response of alumni readers also seemed stronger.

Unfortunately, there is no way to clearly identify the qualities of the magazine that resulted in the success of our non-alumni edition in the marketplace. The Review's content--both editorial and illustration--is surely significant. So are the nature of the magazine's promotion and the characteristics of the marketplace in which that promotion operated. It is likely that all these factors worked in the Review's favor in 1987-88.

Our editorial content was strong, and much of it was timely due, in a major way, to the exceptional work of the Managing Editor, Jonathan Schlefer. At the risk of being unfair to unnamed authors we cite among outstanding major articles the following: "Can We Close the Ozone Hole?" by F. Sherwood Rowland (August/September), "What the Soviets Are Doing in Space" by Peter Pesavento (October), "Power Lines and Cancer" by Louis Slesin (October), "The Next Oil Crisis" by Michael Lynch (November/December), "Superconductors: the Long Road Ahead" by Simon Foner and Terry P. Orlando (February/March), "Cutting the Production of Hazardous Waste" by Joel Hirschhorn (April), "The Japanese View of Economics" by Clyde Prestowitz (May/June), and "The State of the World," an interview of Lester Brown by Senior Editors Sandra Hackman and Marc Miller (July). An extraordinary response, some of it generated by the authors' aggressive use of reprints, was achieved by "Why We Need Hands-On Engineering Education" by Arnold D. Kerr and R. Byron Pipes (October).

Illustration and design continued to receive major attention under the direction of Nancy Cahners, Design Director, and Kathleen Sayre, Design/Production Manager, and the Review was honored by selections in the annual exhibition of the Creative Club of Boston and Print magazine's Regional Annual.

During the year Marshall Goldman, Professor of Economics at Wellesley and Associate Director of the Harvard Russian Research Center, asked to be relieved of his responsibility for four columns a year for the Review. The Editors reluctantly accepted his decision, and their invitation to Professor Bennett Harrison of MIT to replace Professor Goldman was accepted, effective with the July 1988 issue.

The turmoil of recent years in the marketplace for science/engineering magazines subsided in 1987-88, a change that was probably to the Review's advantage: there was less noisy competition for our necessary modest sales and promotion efforts. New direct-mail materials created for Beth A. Rosner, Circulation Director, were more successful than their predecessors in identifying trial subscribers, and mailings to convert trial to regular subscriptions were also successful: in both categories, we met or exceeded industry standards of performance.

The Review's advertising volume held up well in 1987-88, a year when many magazines experienced serious losses in this resource. Much of the credit for this performance goes to our advertising cooperative, The Leadership Network, of which Peter Gellatly, Business Manager of the Review, continues to serve as lead publisher.

Unfortunately, there is no quantitative measure of the success of our "alumni" edition comparable to that of the marketplace for our "national" (non-alumni) edition. But there was important evidence of greater interest in the "alumni" edition during 1987-88. The flow of letters to the editors on MIT-related subjects was greater, and the number of alumni receiving the magazine remained essentially constant despite an increase (from \$15 to \$25) in the size of gift required for a subscription. We take these to be responses to the general editorial quality of the Review and especially to the enrichment of the "MIT" pages than ever before in which were presented more complete reports from classes and courses as well as of Institute affairs. Notable editorial features included a special report on "Assessment and Change in Undergraduate Education" (October); an interview by Susan Lewis, Senior Editor, with Gerald L. Wilson '61, Dean of Engineering (November/December); special reports on Campaign kick-offs in Cambridge, New York, Philadelphia, and Washington; an essay on the 25th anniversary of computer games by Diana ben-Aaron '85, (April); and a summary by Faith Hruby, Associate Editor, of the new emphases being charted by its new dean, Professor Lester C. Thurrow, for the School of Management (May/June). Ms. Hruby joined the staff during the winter, and her efforts were in part responsible for the more effective "MIT" section.

There were two other important changes on our masthead during the year. Alison Bass, Senior Editor, resigned to join the staff of the "Sci-Tech" pages of the Boston Globe; her place has been ably filled by Robert Howard, a journalist specializing for the last decade on industrial and managerial issues related to technological change. And Lori Nollet was promoted to Assistant Production Manager following the resignation of Elizabeth Fullon, who left the Review to join the production staff of the The World Paper.

A major change in the Review's daily life resulted from our move in August 1987 to far larger (if less centrally located) quarters, newly remodelled for our use, in the second floor of Building W59. The distance from the main buildings proved to be a lesser hazard, and the additional space an even greater asset, than anticipated. Among other advantages, the new space has made possible installation of the Compugraphic typesetting and page-make-up system that was a gift of the manufacturer in 1986, and as 1987-88 ended it was becoming clear that this resource--under the skillful operation of Valerie Kiviat, Production Assistant--will be a major asset.

Alumni Information Management

The second phase of our office automation efforts took place with more staff receiving Apple Macintosh computers which are networked together and serve both as terminals and individual work stations. Innovative use of the systems grow as both effectiveness and efficiency have risen.

Continuing work goes forward on the ADDS system during this first year of the campaign. Mounting costs have led us to seek an in-depth look at the system which will be done by an outside consultant during the coming academic year.

The new on-line accounting system occupied a great deal of time and has resulted in more timely and effective reporting being available to the Association.

Rick O'Connell and David Pires have joined the staff in the systems area.

Administration

Our staff in New York was able to relocate to its new space in the city during the last year.

Our new financial system has proved to be of significant value in our managing the operation of the Association. As the experience of line managers grows this system will enable a much improved planning and control cycle.

Finally, the need for additional staffing and replacement staffing have occupied a good deal of our personnel effort.

WILLIAM J. HECHT